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COMPUTER MAPPING
as an aid in
AIR POLLUTION STUDIES

VOLUME TWO: INDIVIDUAL REPORTS

REPORT A
ST. LOUIS REGION STUDY -- PART I

by

Norma Bogen, et al.

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16. Abstracts

A detailed report is presented of general mapping techniques used during a demonstration study of conceptual, methodogical, and technical approaches to air pollution problems. This report of the St. Louis Region study is divided into two sections; the map system and data banks, and the maps produced in the study. An appendix of computer graphics is also included.

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COMPUTER MAPPING

as an aid in

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PREFACE

From July 1, 1968 through December 31, 1969, the Laboratory for Computer Graphics and Spatial Analysis conducted a demonstration of several conceptual, methodological, and technical approaches to problems in the field of air pollution, employing computer-produced maps and allied displays. This work was done under a grant (No. 68A-2405D) from the Division of Control Agency Development, National Air Pollution Control Administration (NAPCA), Public Health Service, U. S. Department of Health, Education, and Welfare.

The results of this study, taken in its entirety, should make an important contribution to the work of Federal, state, and local air pollution agencies, especially in their efforts to determine the best control strategies for use in air quality control regions. The computer is an ideal tool for relating and combining sets of data, and for considering alternatives. For instance, graphic displays can contribute significantly to the evaluation of both short-term and long-term control strategies.

In demonstrating "the use of computer graphics as a means for more clearly portraying data related to the sources, distribution, and community effects of air pollution," the primary emphasis was on case studies for specific areas. The secondary emphasis, to support and complement the case studies, included:

(a) "the development of instructional manuals covering the procedures required for the preparation and interpretation of computer maps of various kinds, as related to air pollution,"

(b) "the use of certain newly developed techniques for describing, analyzing, and portraying quantitative surfaces and movements relative to such surfaces, as related to air pollution," and

(c) "an appraisal of alternative equipment, techniques, and computer programs presently or potentially available for the production of computer graphic displays pertinent to air pollution."

The case study regions were selected in consultation with NAPCA. Considerations included:

(a) sufficient air quality, emission, and related socio-economic and meteorological data--spatially distributed over the region--to enhance the likelihood of adequately demonstrating the mapping techniques;

(b) representative problems in data handling and mapping so that the techniques demonstrated would have applicability to as many other areas as possible;

(c) special problems in data handling and mapping so that as many techniques as possible could be adapted, developed, and tested;

(d) areas of which NAPCA and the individual investigators had special knowledge and could therefore utilize relevant research to enhance the study;

(e) areas where an immediate interest in mapping had been expressed for on-going Federal, state, and local air pollution activities.

Other research was undertaken to support and complement the case studies, and, in particular, to provide:

(a) the widest possible distribution of the mapping programs and accompanying explanation of the techniques through

    i) copies of the Laboratory's SYMAP Computer mapping program,
    ii) an introductory correspondence course in the SYMAP program,
    iii) general program description and supplementary explanation for the existing user-manuals;

(b) a general review of present and potential hardware, output devices, and programs applicable to computer graphic displays of air pollution and related data;

(c) means for predicting, projecting, and correlating air pollution and related data, utilizing the latest knowledge in planning, geography, and spatial analysis in general;

(d) dissemination of information on approaches and techniques to Federal, state, and local air pollution agencies, especially for use in the air quality control regions.

The final report is divided into two parts: Volume One: Summary, and Volume Two: Individual Reports--the detailed reports on the case study areas and the technical reports related to other research undertaken. The pertinent graphic displays are included with the appropriate individual report and a complete set is provided with the Summary Volume.

Introductory sections describing the air pollution and related data used are provided in the major case study reports for St. Louis and Kansas City; these should be referred to by anyone unfamiliar with the types of data and problems existing in this field. Detailed discussions of special data handling and mapping techniques are presented either as appendices to case study reports, or in separate technical reports.

The Summary Volume includes a discussion of all the areas of research undertaken and contains the complete table of contents for the reports of Volume Two. This should provide a useful reference of the special problems and technical discussions of one report which may be of interest to the reader of another detailed report.

The St. Louis Project was the major case study region examined under the demonstration grant. Consequently, the results are presented in three separate reports: Part I deals with the general mapping techniques: Part II with the statistical analyses undertaken; and Part III with a study of power plant load shifting.

The St. Louis Region Study--Part I--is presented here as Report A of Volume Two. It is divided into two sections--the map system and data banks, and the maps produced in the study--in addition to an introduction discussing the area and the available data. An appendix of computer graphics produced is included.

The data used in the study was provided by the Division of Control Agency Development, through the efforts of Robert Stephenson, Project Officer. The assistance of Jerry Mersch, NAPCA, the Department of Public Safety, Division of Air Pollution Control, City of St. Louis, and the Division of Air Pollution, St. Louis County Health Department, is also greatly appreciated.

This study was under the direction of Norma Bogen, with the assistance of Donald Shepard, Steven Fosburg, Helen Mansfield, Johnny Kirkland, and Katherine Mickey.

The report was principally prepared by Norma Bogen, with the assistance of Steven Fosburg, and the introductory section was adapted by Gail Howrigan.

John C. Goodrich, Editor
Cambridge, Massachusetts
April 1970

REPORT A
ST. LOUIS REGION STUDY - PART I

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1. INTRODUCTION

1.1 BACKGROUND: PHASE II PROJECT REPORT(1)

1.1.1 Origin of the Interstate Air Pollution Study

The Interstate Air Pollution Study for the St. Louis-East St. Louis Metropolitan Area was a project done cooperatively by the Technical Assistance Branch of N.A.P.C.A. and state and local agencies. The objectives were to assist the two States and several local agencies in strengthening and coordinating their air pollution activities and control programs, and to augment existing knowledge about the nature and distribution of air pollution and the factors affecting prevention or control.

The Interstate Air Pollution Study was undertaken as a result of independent requests from official groups in St. Louis, Missouri, and East St. Louis, Illinois, for aid in solving odor problems and in drafting air pollution ordinances. Preliminary investigation indicated that the air pollution problems of the two-state metropolitan area were such that piecemeal efforts would be ineffective. Accordingly, in the early spring of 1962 it was decided that there was sufficient local interest to undertake an extensive cooperative study.

1.1.1.1 Organization

In the early fall of 1962 agreement was reached to carry out the study project in two phases. Phase I, to last six months, was to make an appraisal of air pollution in the St. Louis-East St. Louis Metropolitan area and to prepare a report that would indicate areas of major importance to be studied in more detail during Phase II; Phase II would last an additional year. The data gathered in the two phases would then be analyzed and recommendations made for an "air resource management program" to be presented to the citizens of the two-state metropolitan area.

1.1.1.2 Study Area

The Study area consisted of St. Louis, St. Charles, and Jefferson Counties in Missouri and St. Clair, Madison, and Monroe Counties in Illinois, plus the City of St. Louis. The area encompasses the St. Louis Standard Metropolitan Statistical Area (SMSA) plus Monroe County, which brings the total population of the study area (as of 1960) to 2,075,500. Approximately 95% of the population and most of the industrial area are concentrated in a 400-square-mile, centrally located urbanized area.

1.1.1.3 Operation

To accomplish the Study's purpose, the following activities were to be undertaken during Phase I.

Tallying air pollution complaints received by various branches of local government.

Inventorying air pollution sources and their locations, locating major single sources and groups of sources.

Indicating the growth trends of the area, in regard to population, economics, industry, transportation, and power.

Compiling in useful form existing meteorological, air quality, sociological, and economic information that bears upon air pollution.

Conducting an odor survey to define the problems and to develop a methodology for their solution.

Evaluating existing statutes pertaining to air pollution and preparing guidelines for an ordinance for communities desiring one.

Surveying existing programs in air pollution for their relation to planning and zoning.

Surveying official and industry opinion for their attitudes and desires concerning changes.

Performing additional work and summarizing past work on the effects of air pollution on vegetation, with the objective of a continuing vegetation damage surveillance activity.

Conducting a public opinion survey to assist in developing Phase II and long-range community programs in other areas.

Determining air quality within the limitations of available resources. Maps of sampling station networks were to be prepared for each kind of pollutant to be measured, showing the number and distribution of stations needed to give data of a certain probable reliability.

During Phase II, several activities were grouped into three priority classes according to their importance to the achievement of project goals. The first priority group, those "essential to reaching project goals", included:

Developing an air resource management program plan for the Project area, with a time schedule for implementation and a plan for financing the program.

Continuing the air quality measurement program developed during Phase I, redesigning and modifying it for local agencies to operate or finance for central operation.

Conducting a detailed emission inventory, to serve the needs of an air resource management program, and undertaking research work to test the mathematical diffusion models.

Setting up a complaint-recording system, with the information being made available periodically to interested agencies and individuals.

Establishing a subcommittee on ambient air quality standards to locate and bring together the technical competence and group interests needed to determine such standards, indicating studies and plans necessary to their formulation.

Establishing another subcommittee to prepare ordinances, rules, and regulations, building upon the activities started in Phase I with the City of East St. Louis, and St. Louis County.

Items of secondary priority included performing further odor studies; continuing the vegetation damage surveillance activity; developing an air pollution potential forecasting activity; conducting an industry management opinion survey directed toward finding areas of agreement on air pollution programs; continuing the activity of the subcommittee on education and information in the form of short publications covering the findings of Phase I; assisting in the evaluation and/or solution of specific air pollution problems in cooperation with industry and regulatory agencies; and analyzing the potential impact of air pollution on the future of central areas of cities in the project area, in cooperation with planning commissions and local groups having an interest in the future of central city areas.

The third priority group included items that are primarily of a research nature, not dependent upon the action of the local cooperating agencies for successful completion: continuing assistance with studies in epidemiology, materials deterioration, and other areas as appropriate; performing further fluorescent particle diffusion studies directed toward determining airflow characteristics over the urban area; and testing of mathematical diffusion models, providing for a detailed sulfur dioxide emission inventory.

1.1.2 Air Pollutant Emission Survey

Through an emission inventory, information relating to the quantities of the various pollutants released, the relative contribution of pollutants from the different source categories, and the geographical distribution of pollutant emissions within the study area may be obtained.

An emission inventory was conducted during 1963-64 as part of the St. Louis-East St. Louis Interstate Air Pollution Study. Although the study covered an area of 3,567 square miles, more than 95 percent of the population and almost all of the industrial activity are located in the 400 square miles of the centrally located urbanized part of the study area. The pollutant emission data presented can be almost entirely attributed to this urbanized portion of the area.

1.1.2.1 Pollutants Considered

The pollutants considered in this survey are those emitted in large quantities from a variety and multitude of sources dispersed throughout the area. Included are aldehydes, carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, particulates, and benzo(a)pyrene. The incompleteness of data relating to pollutant emissions from some processes and fuel uses has resulted in the omission of some air pollutants and air pollution sources in the area. For the most part, these omissions have been confined to source categories or sources contributing relatively small quantities of pollutants. The emission inventory should therefore be fairly representative of total area emissions of the principal pollutants.

In addition to the seven major pollutants included in the survey, other pollutants--largely chemical by-products (such as aluminum oxide, ammonia, chlorine, fluorides, hydrogen sulfide, nitric acid, potassium cyanide, and others)--are generated and released. Almost all of the major types of industrial activity are present in the area. The most prevalent, in terms of employment, are the fabricated metals, primary metals, food and kindred products, and chemical products manufacturing industries.

1.1.2.2 General Sources

The sources of air pollution in the Study area may be subdivided into the five following general categories:

a. Fuel combustion in stationary plants;
b. Combustion of refuse material;
c. Fuel combustion in transportation vehicles;
d. Industrial process emissions; and,
e. Solvent evaporation.

The procedure for conducting an emissions survey consists of two parts. The first part involves collection and compilation of basic data such as quantities of fuels and refuse materials burned, the combustion equipment and techniques employed, selected chemical analysis of fuels used, and the quantities and types of materials handled or processed. In the second part of the survey, average emission factors are applied to the measured data to translate these quantities into pollutant emission rates.(2) An emission factor represents the average emission rate of a pollutant per unit quantity of material handled, processed, or burned. Because emission factors are averages for a particular industry or fuel group, it should be borne in mind that their application to individual plants or small groups of similar plants or processes may result in a great disparity between the actual and calculated emissions because of the differences in emission rates among the plants or fuel users within a given category.

1.1.2.3 Fuel Combustion in Stationary Sources

The combustion of coal, fuel oil, and gas used to supply heat and power for industries, steam-electric utilities, households, and commercial establishments **constitutes** the major source of particulates, oxides of sulfur, and oxides of nitrogen present in the air of the Study area. The emissions of pollutants are not only dependent upon the types and **quantities** of fuels burned but also on the chemical composition of fuels, firing techniques and equipment employed, and the efficiency of air pollution control devices used.

Industrial uses and steam-electric utilities together account for nearly 60 percent of the area totals of these pollutants.

Fuel consumption data for the Study area were obtained through the use of a variety of techniques and from numerous information sources, varying from individual contact (mostly by questionnaires) to the use of city or metropolitan area totals as reported by the U. S. Bureau of Census or by national fuel associations.

The major fuel users are located in the St. Louis-East St. Louis-Granite City core area and in the outlying industrial town of Alton. Residential fuel use is, of course, distributed over the entire Study area.

1.1.2.4 Solid Waste Disposal

Refuse material generated within the Study area is disposed of through municipal and on-site incineration, open-burning dumps, backyard or on-site open burning, sanitary landfills, and salvage operations. The pollutants generated by refuse burning are primarily hydrocarbons and particulates. Open burning, on-site or at dumps, accounts for more than 90 percent of these pollutants from this source category.

Solid waste disposal sites and municipal incinerators are distributed over most of the Study area, although there is some clustering in the St. Louis-East St. Louis-Granite City core area.

To estimate the pollution load released by the combustion of refuse material, the quantities of refuse material incinerated and burned openly had to be determined. This procedure was hampered by the lack of authentic and complete data. Utilizing the available resources in the only way possible, to estimate the quantities burned on site was to assume an average per capita production of waste materials(3) and to further assume that the difference between this total quantity generated and the quantity disposed of at collection sites was that disposed of on-site. Any interpretation of the data then had to be viewed within the accuracies and limitations of these assumptions.

1.1.2.5 Transportation Sources

Road vehicles (automobiles, buses, and trucks) are by far the most important community-wide source of air pollution. The quantity of gasoline and diesel fuel consumed in a community is an index of the amounts of the various pollutants released to the air from the operation of automobiles, buses, and trucks. The evaporation of gasoline from gas tanks and carburetors adds to the pollution arising from vehicular traffic; the loss is assumed to average 1.5 percent of gasoline sold by volume. (4)

More than a million tons of carbon monoxide, about 220,000 tons of hydrocarbons, and over 40,000 tons of oxides of nitrogen are contributed annually by the movement of vehicular traffic in the area. The contribution of diesel fuel is almost insignificant in comparison with that of gasoline.

1.1.2.6 Industrial Process Emissions

The quantities of the different pollutants discharged from most industrial and some commercial establishments are attributable to two general types of operations--the pollutants generated by the combustion of fuels (already discussed), and the pollutants produced and discharged from the industrial process. Emission factors were available for only a small number of processes and industries. Also, quantities of pollutants discharged or the production data upon which to base emission estimates were not available in all cases.

1.1.2.7 Summary

An examination of the results shows a high incidence of industrially-generated particulates in Madison, St. Clair, and Jefferson Counties. Sulfur oxides were high in St. Clair, St. Louis, and Madison Counties. Jefferson and St. Louis Counties had the largest amounts of nitrogen oxides, while St. Louis City had the overwhelming preponderance of hydrocarbons.

The following is a brief summary of pollutant emissions and sources in the Study area:

a. Particulate matter is emitted primarily from the combustion of coal (56%), various industrial processes (27%), and the open burning of refuse (10%).

b. More than 90 percent of the sulfur oxide emissions are discharged during the combustion of fossil fuels, with coal contributing more than 87 percent and fuel oil 4 percent of total emissions.

c. Oxides of nitrogen are discharged primarily from the burning of coal (51%), transportation sources (35%), and burning of gas (7%).

d. Motor vehicles emit more than 63 percent and open burning of refuse almost 23 percent of the total hydrocarbons released.

e. The major source of carbon monoxide is the operation of gasoline-powered motor vehicles, which emit almost 98 percent of the total.

1.1.3 Air Quality Measurements

Since the development of an effective air resource management program begins with identification of the pollutants in the air and determination of the quantity and origin of each type, an air quality measurement program was designed and operated in the Metropolitan St. Louis area. Thus, with the physical aspects of the air pollution problem defined, air pollution effects data and criteria as well as opinion surveys could be used to set the air quality goals. Using this base together with the pollutant emission inventory, the emission control plan could be designed. Finally, with the control plan in effect, the air quality measurement program was to be used to monitor the air quality to assure that goals are attained.

There are essentially two types of air pollutants--gases and particulates, the latter further classified as suspended and settleable. The gaseous pollutants, molecular in size, remain mixed in the atmosphere because their density is so nearly that of the air. Suspended particles are so small (1 to approximately 100 microns) that they remain suspended in the atmosphere for long periods of time, while the settleable ones are much larger and heavier, settling out of the air close to their source.

1.1.3.1 Gaseous Pollutants-Sulfur Dioxide

Sulfur oxides are of interest in an air quality control program because of : (a) their harmful effects on the health of humans and animals, (b) their demonstrated harmful effects on vegetation, and (c) their economic effects as evidenced by materials deterioration and metal corrosion.

Two types of West Gaeke samplers were used during the study. The automatic sequential sampler collected twelve 2-hour samples over a 24-hour period, and the 24-hour sampler collected one sample over a 24-hour period. These measurements were carried out from December 1963 to February 1964, and December 1964 to February 1965. A network of twenty 24-hour samplers produced results ranging from 0.00 to 0.24 ppm. The network of forty 24-hour samplers ranged from 0.00 to 0.26, and the network of ten 2-hour sequential samplers resulted in a range of 0.00 to 0.86.

The locations of 19 of the 24-hour sampler stations were the same for the winters of 1963-64 and 1964-65. Comparison of the results shows that the sulfur dioxide concentrations were significantly higher for the winter of 1964-65 than for the previous one. It is not certain whether this is due to actual greater concentrations of sulfur dioxide, or to meteorological conditions more conducive to high air pollution during the 1964-65 season, or perhaps to the possibility that the 1963-64 samples faded before analysis could be carried out.

Comparison of the matched pairs of arithmetic monthly means from the ten stations that had both 2-hour sequential and 24-hour samplers during the 1964-65 network operation indicates that the monthly 2-hour sequential sampler arithmetic means were 15 to 24 percent greater than the monthly 24-hour sampler arithmetic means.

The majority of the sites show only minor diurnal variations in the sulfur dioxide concentrations. Normal morning peaks around 6 to 8 a.m. reflect the increase in human activities in the morning, while the 2 to 4 p.m. peak may indicate an industrial influence or a meteorologic-topographic influence.

To point up the importance of directional influence on sulfur dioxide levels and to provide a guide for design of the air use plan, a directional analysis was made from sulfur dioxide data collected during the 1963-64 winter season. The directional analysis used supports the observations drawn from the pollution roses and directly confirms that the central part of the study area has considerable effect on sulfur dioxide levels in outlying areas, pointing to the areas having the greatest sulfur dioxide source strength as being in the East St. Louis area and the area to the southwest of Granite City.

The correlation of sulfur dioxide concentrations from the 1963-64 network with stability conditions shows that high wind speeds rather than high thermal mixing result in the lower concentrations.

An attempt to demonstrate the influence of a "heat island" effect did not show a consistent pattern, possibly because of the overriding influences of wind speed and source strength-direction.

1.1.3.2 Particulate Pollutants-High Volume Air Sampler

Suspended particulate samples were collected with high-volume air samplers. The particles consist of dust, smoke, and fumes, resulting from incomplete combustion of fuels and wastes, gravel handling and crushing operations, metallurgical and chemical processes, grain handling and earth moving operations, and many other similar processes.

The sampling schedule for the high-volume sampler network was a combination of continuous weekday and random samples. The sampling period ran from July 1, 1963, through June 30, 1964. Continuous weekday sampling was performed from September to March of that year, while predetermined random sampling was carried out during the remainder.

High-volume air samplers were operated at 17 sites to collect suspended particulates. The geometric means for the year ranged from 10.98 micrograms per cubic meter at a site in a light commercial area, to 221.81 micrograms per cubic meter at a site surrounded by industry and burning dumps.

The monthly, seasonal, and yearly geometric means for all sites show October as the maximum month (148.32 micrograms/meter^3) and June the lowest

(91.10 micrograms/meter^3); accordingly, fall and spring are the highest and lowest seasons, respectively. The yearly geometric mean based on random days was 98.77 micrograms/meter^3 and 107.86 micrograms/meter^3 based on all results. From an isopleth map of geometric means and the 1960 population density, it can be determined that approximately 84,000 people lived in areas having concentrations greater than 150 micrograms/meter^3.

A statistical comparison of the results from the weekday and random schedules was made to determine the validity of the random schedule. This comparison showed that the 100-day random sampling schedule could be used to estimate annual and season means within ± 20 percent of the true geometric mean at 95 percent confidence limits. A random schedule of 250 to 300 days would be required to estimate monthly means with the same degree of confidence.

Data from ten of the sites were tested to determine whether the geometric mean and its standard deviation or the arithmetic mean and its standard deviation described the data better. For all ten sites, the geometric means were nearer to the 50th percentile value than were the arithmetic means. Other tests bore the same results, leading to the conclusion that the geometric mean and its standard deviation should be used to describe each station's data distribution.

Analysis of the frequency distribution shows that for most of the sites the summer season data had the least slope or standard deviation and those of the fall had the greatest. These findings are attributable to the meteorological conditions, which during the summer were more uniform with only a very few short-term inversions, and more variable in the fall with more long-term inversions.

Results ranged from 182 micrograms/meter^3 to 1,800 micrograms/meter^3 on the basis of the 1 percent occurrence level (99 percent of the samples). This tenfold differential is indicative of the great variation among residential, commercial, and industrial complexes in the St. Louis area.

In addition to the usual statistical approaches used to analyze high-volume air sampler results, a new approach was made to reflect the influence of wind direction on pollution levels. In this new technique, "pollution roses," similar to wind roses, were prepared by substituting pollution levels for wind speeds. The pollution rose for one representative station indicated that the south wind frequently brought large amounts of suspended particulates.

Data from the weekday sampling schedule, because of their greater reliability, were used in the preparation of the pollution roses, as were meteorological data from Lambert Field. The pollution roses show the west to northwest and south to southeast sectors had the most frequently occurring winds.

1.1.4 Results of Surveys

1.1.4.1 Air Pollution Complaints

Detailed records of air pollution complaints were compiled and summarized from local agency files. Information was categorized by: type of pollution, source of pollution, effects of pollution, date complaint received, and method by which it was received (telephone, letter, or personal visit). The reports revealed that odors are the type of pollution most often complained about, industrial sources were most often cited, and complaints reached peaks in July and December.

1.1.4.2 Odors

During Phase I, two odor surveys were carried out in which the most frequently detected odors were those associated with chemical manufacturing (25% of the total observations), followed by those resulting from food processing (16%), burning refuse (16%), and putrid odors (6%).

The expanded odor survey of Phase II tried to determine what areas had odor problems, what kinds of odors affected each area and which are most undesirable, when the odors are prevalent, what meteorological conditions are associated with their occurrence, where the sources are located, and the interjurisdictional and interstate problems related to odor control.

It was found that the most objectionable odors occurred near chemical and rendering plants, and that the most odorous areas tended to be near or within commercial and industrial areas. Animal, decomposition, and chemical odors were most frequently described as unpleasant. The highest percent of positive odor observations were recorded for the 8:00 p. m. observation time; generally more odors were detected at night than during the day. The meteorological conditions associated with a high frequency of positive odor observations were: wind speeds less than 10 m. p. h., stable atmospheric conditions, no rain, and winds out of the east (for St. Louis and St. Louis County) and south (for Illinois). Many of the major odor sources are on strips of industrially zoned properties adjacent to the Mississippi River and in other industrial zones.

1.1.5 Meteorology and Topography

The St. Louis area experiences the meteorological conditions typical of most Great Plains cities that are not influenced by major natural features such as mountains or large bodies of water. Winters are brisk but seldom severe, with several periods of mild weather and occasional short spells of extreme cold. Summers are warm, whereas spring and fall are characterized by moderate temperatures.

Marked variations in day-to-day conditions are provided by changes from warm, moist air flowing up from the Gulf of Mexico during some periods to cool, dry air from the Northern Plains during others.

1.1.5.1 Topography

The topography of the Study area is gently rolling, with elevations from 480 feet above sea level in the downtown area to 550 feet at Lambert Field, 22 miles away, and a slight ridge rising to 600 feet in between. A 10-mile wide flat area in the Illinois portion of the Study area, the American Bottoms, is flanked to the east by a crescent-shaped bluff rising to an average of 640 feet above sea level. The Study area is generally free of major land surface features that would strongly influence airflow characteristics over the area.

1.1.5.2 Meteorological Parameters

Stability in the atmosphere may be measured by the vertical variations (lapse rate) of temperature. A parcel of air lifted through the atmosphere experiences an increase in volume and a decrease in temperature. If the parcel is lifted quickly enough to prevent exchange of heat with its surroundings, it will cool at a standard rate (the adiabatic rate, $5.4^{\circ}F/1000$ feet). If the air mass is warmer or cooler than its surroundings when released at its new position, it will tend to rise or sink, as the case may be. When the tendency is to return the air mass to its level of origin, the atmosphere is stable. If, however, the tendency is to move the air mass further from its origin, conditions are termed unstable.

A decrease of temperature with height more rapid than adiabatic is an unstable condition. An increase of temperature with height is an inversion, and is most stable. The gradations between these two conditions produce a variety of stability conditions.

A stable condition inhibits the creation of eddies and thus the diffusion of air pollutants, whereas an unstable condition supports the creation of eddies and accelerates the diffusion of air pollutants.

The principal effect of wind direction is readily apparent since it determines the part of a city that may be affected by the transport of pollution from given sources or areas. Wind speed and atmospheric stability largely govern the degree of dilution of effluent before reaching a given location downwind from a pollution source.

Meteorological data were obtained from the Weather Bureau Station at Lambert Field, from which stability classes were determined by the Pasquill-Gifford-Turner stability classification criteria. These criteria are based on surface wind speed, daytime solar insolation, and nighttime cloud cover.

1.1.5.3 Air Pollution Climatology

The principal effect of temperature on air pollution is that space heating is required in cold weather. Heating requirements are measured in degree-days, defined as the number of degrees the mean temperature is below 65°. Emissions from space-heating equipment are very nearly proportional to the number of degree-days; hence, degree-days may be used to estimate daily and seasonal variations of pollutants emitted from such sources.

Thunderstorm days are of interest since a thunderstorm is associated with unstable conditions and strong vertical movements, effective in carrying pollutants aloft. Precipitation alone is less important, although there is some tendency for rain or snow to wash pollutants out of the atmosphere. Spring and summer are the best seasons for removal of pollutants from the atmosphere by this washout and thunderstorm activity.

Stability in the lowest layer of the atmosphere varies in a diurnal pattern, normally being stable at night and unstable in the afternoon. The height to which the unstable layer develops is defined as the maximum mixing depth, and, taken with wind speed, represents a volumetric indication of the dilution of air pollutants, since the scale and applications are generally area-wide. The product of maximum mixing depth and average monthly wind speed at or near the surface gives a qualitative idea of atmospheric dilution for an area. This concept indicates that for St. Louis the atmosphere is least able to dilute pollutants during the fall and winter seasons when dilution is most necessary, though its application is limited to afternoon conditions.

Frequency of temperature inversion is another useful climatological parameter for describing atmospheric dilution. The percentage of time during which inversions occur, thereby preventing pollutants from mixing freely into a deep layer, is highest in fall.

1.1.5.4 Urban and Topographic Effects

Metropolitan areas impose their own effects upon the atmosphere. The city acts as a heat island, or heat reservoir, storing up heat by absorption from the sun's rays during the day and releasing heat at night. Space heating during the colder months adds to the effect. The heat island has two direct effects: nighttime temperatures remain higher than in the surrounding countryside; and the nighttime inversion, which is usually based on the ground, is lifted to some distance above ground over the city itself.

The heat island may be described as a "bubble" of air, with stability conditions in the middle (or neutral) range, enclosed within a general inversion. The model suggests that the warm air would rise in the central area, flow outward along the surface of the bubble, lose heat to the surrounding atmosphere, sink to ground level at the outer edges, and return to the central area along the ground from all directions. This flow pattern would permit pollutants emitted in the central areas to eventually reach intermediate areas from the opposite direction. In spite of modifications to this pattern, it should be expected that pollutants emitted at almost any source within the bubble would reach the central area, and that average concentrations of any pollutant emitted within the bubble would increase with time until the condition is terminated or the source eliminated. A general warming or an increase in wind speed would be sufficient to eliminate the bubble.

Because air becomes denser and settles as it cools, the nearby low-lying areas are reservoirs of cool air, creating frequent and intense inversions. The juxtaposition of the cold pool of air in the American Bottoms and the heat island of the City of St. Louis thus produces complex wind patterns, the effect of which is to retain effluents in the city and bottom area during night and early morning hours.

1.1.55 Meteorological Instrumentation in the St. Louis Area

The Study drew its data from the Weather Bureau, Cooperative Climatological Stations, and special meteorological instrumentation sites in the St. Louis area. During the atmospheric dispersion field experiments, special equipment and instruments were used to determine more accurately the character of the atmosphere at low levels. Balloon-borne instruments and pilot balloons were used to measure the variation of temperature and wind with height.

1.1.5.6 Summary

Since dispersion and, to some extent, emission of atmospheric pollutants are strongly dependent upon meteorological conditions, in a study of air pollution levels one must know whether meteorological conditions are representative of those usually encountered. With this knowledge one can estimate the concentrations that may be expected under average conditions and under other conditions as well.

Data showed that five months of the period from July 1963 through June 1964 could not be considered representative. July, April, and June were much above normal in wind speed; diffusion conditions for those months therefore were better than average. With an average wind speed slightly above normal and heating requirements much below normal in October, measurements of pollutants resulting from space heating would be expected to be below normal. December, with an average wind speed slightly below normal, was much above normal in heating requirements and therefore in pollutants resulting from space heating. In all other months, both wind speed and heating requirements were near normal.

1.1.6 A Proposal For an Air Resource Management Program

The Study's resulting recommendations for an air resource management program are of two kinds--those aimed at organization to effect the necessary changes and controls, and those aimed at the specific activities a continuing air management program will require.

The first group includes proposals for strengthening air pollution activities and agencies in both states and jointly establishing a functional linkage between regulatory and urban planning activities to prevent land- and air-use conflicts leading to air pollution, as well as planning for governmental air pollution expenditures at a level of 50 cents per capita by 1970.

Proposals for activities began with an emphasis on control of pollutants in the immediate future through utilization of the information and data provided by the Study: a continuing air-quality monitoring program and a continuing emission inventory; goals and standards based on air-quality criteria; a thorough knowledge of the conditions influencing the transport of air pollutants; urban planning decisions, air pollution control decisions, and resulting ordinances based on air-quality information and relationships between air quality and effects; and air-use plans.

1.2 OBJECTIVES OF THE STUDY

The St. Louis Project of the Air Pollution Demonstration Study focused on levels of pollution, demographic and housing characteristics, and the relationships among these variables. The specific objectives were: (i) to map levels of air pollution; (ii) to describe the socio-economic structure of the area in spatial terms; (iii) to relate levels of pollution to demographic characteristics in order to indicate the impact of pollution on various segments of the population; and (iv) to describe the statistical relationships among the variables.

1.2.1 Techniques Used

The primary technique employed was the SYMAP Computer Mapping Program. In addition, the GRID Program--which manipulates information presented in the form of a rectangular grid--was used in combination with the SYMAP program to make comparison maps of two or more sets of data. Regression analysis was used to determine the statistical relationships among the variables and to describe the surfaces of the data.

The contouring technique in the SYMAP program is based on an interpolation function and therefore represents an approximation of the surface. As such, it describes trends rather than the exact value at any particular point, although the value at the location of a monitoring station itself may be considered to be "exact." The degree of exactness for other locations depends somewhat on the distance between stations. Socio-economic data, moreover, cannot be considered to be "exact" at any one point since the data values in fact describe an area (census tract) rather than a point. It follows from this that all maps should be viewed as displaying general tendencies of the data, rather than indicating precise values at all locations.

1.2.2 Topics Examined

This report on the St. Louis project is divided into two major parts. In Section 2, the map system and data banks are described in some detail. The map system for the project was designed to accommodate data collected in terms of census tracts and the grid coordinate system of the Interstate Air Pollution Study. The data used included the air quality data from the Phase II Project Report of the Interstate Air Pollution Study, supplemented with 1960 United States Census data and land use data from the city of St. Louis.

Section 3 is devoted to the maps produced in the study, including the direct mapping of air quality and socio-economic variables and the comparison mapping of air quality and socio-economic data.

Although this project focused on a particular study area, the St. Louis Metropolitan Area, the emphasis was on applicable techniques rather than on specific results as they pertain to St. Louis. At the same time, the techniques have been used in such a manner that the conclusions do in fact give an overview of the area in terms of the objectives of the study. The statistical analysis, however, should be regarded as indicative rather than conclusive. Further work with larger bodies of data is called for, and comparisons of the results from year to year is required in order to yield valid conclusions or to construct a useful descriptive model of the area.

2. MAP SYSTEM AND DATA BANKS

2.1 DESIGN OF THE MAP SYSTEM

The map system--designed to accomplish the cited objectives of the project--was planned to accommodate the kinds of data available and to permit comparison between data collected on the basis of different data zones. The system included the two base maps described below, both prepared using the SYMAP program:

i) base map of the St. Louis Standard Metropolitan Statistical Area (SMSA-1960 census tracts). The centers of the census tracts are defined in terms of latitude and longitude (see Figure A-1);

ii) base map of the air quality monitoring stations network (see Figure A-2). The locations of monitoring stations are defined in relation to the grid coordinate system used in the Interstate Air Pollution Study.(5) The outline of this map approximates the limits of the area defined in the Interstate Study; the map was also extended to the outline of the SMSA to coincide with the limits of Figure A-1.

The two base maps are part of one system with a common origin and scale. The system is designed so that data collected in terms of either locational designation--census tracts or the site coordinates of the grid system--can be mapped directly or manipulated in various ways to point out particular relationships. Maps of the entire study area or portions thereof can be produced at any specified scale.

After a preliminary exploration of the objectives of the study and the type and availability of data to be used, a system of maps was designed with rectangular outlines; the boundary of the SMSA was not indicated and only a minimum number of legends were used. This first stage represented a "rough draft" of the final base maps, and could be used for testing purposes. In many instances, this kind of map can also serve as a "final" map, particularly when data locations can readily be identified in terms of a grid system--as in the air pollution study. However, since one of the objectives of the study was to relate air quality data to socio-economic data--the latter data being available by census tracts for an area visually and spatially identifiable by an outline on a map--it was decided to define a boundary outline for the study area in a second stage. In this second stage, additional legends were added to the map to identify the area and to clarify the purpose of the maps.

2.1.1 Source Maps

U.S. Geological Survey (U.S.G.S.) topographic maps(6) were used to provide the original dimensions for the base maps. These source maps included both latitude-longitude designations and grid coordinate designations. Thus, a selected location could be specified in terms of either designation, relative to a common point or origin. This point in common is referred to as the (0., 0.) point of the latitude-longitude, grid coordinate, and SYMAP base map systems. To produce the base maps, all measurements were made in inches from this (0., 0.) point.(7)

2.1.2 Outline of Base Maps

In order to produce maps with a rectangular outline for the first stage of the map design process, the outline of the Census Tract map (Figure A-1) was determined by selecting four extreme points that were sufficiently extensive to include all Census tract centers as defined by the Census Bureau.(8) These extreme points were in terms of latitude and longitude, whereas for the monitoring station map (Figure A-2), the extreme coordinates were in terms of the state plane coordinate system. As noted previously, these extreme points were also increased to produce an outline coincident with that of Figure A-1.(9)

In the second stage of the map design process, the outline of the SMSA was defined in terms of latitude and longitude from the source map.(10) A much smaller and more manageable source map could have been used; the outline could have been digitized or manually measured in inches, and then converted to the scale of the original source map. This latter method was not used, since there was no single map at a smaller size that included the entire SMSA and all of its census tracts. The various census maps that were available covered only portions of the SMSA and were at varying scales. In addition, the degree of accuracy of the census maps was not known. It was therefore felt that to maintain a relatively high degree of accuracy, it would be more suitable to take all dimensions from the original U.S.G.S. maps.

2.1.3 Otolegends

Various legends could have been used to improve the clarity of the maps. Only a limited number of such legends were used so as not to obscure the mapped data. The Mississippi and Missouri Rivers were indicated by a continuous white line Otolegend--or, in some cases, by a line of asterisks or I's--a single character in width. A north arrow and map scale were also used, as well as a title block. "Tick marks" were used on the right and top borders to indicate latitude and longitude and on the left and bottom borders to identify grid coordinate locations. On the air quality maps, the approximate limits of the Interstate Air Pollution Study Area were indicated.(11)

County lines were also computed, but were not used after the initial testing since they tended to obscure too much of the data at the scale of the final maps. On some of the air quality maps, the outline of St. Louis City was used to improve the clarity of the mapped data.

Although a series of Otolegends may theoretically be used with maps of varying size or scale, tests have indicated that when maps are sufficiently small in size, the Otolegends may interfere with the reading of the map, or there may not be enough room to accommodate all the original Otolegends. In addition, when the map scale is shown by an Otolegend, it may not be accurate at all map sizes. Accordingly, in this study six sets of Otolegends were used to accommodate the various sizes of maps that were most frequently produced. The Otolegends for each set differ somewhat in the amount of detail, especially betwen census tract maps and air quality maps. Initially, the Otolegends were changed for each map by using the appropriate Otolegend package or card. As the study progressed, the Otolegend packages were placed on tape, with the appropriate set being called by a computer program.

2.1.4 Data Points

The data point locations for the census tract map (see Figure A-1) were defined in terms of latitude-longitude designations provided by the Bureau of the Census,(12) and converted to inches by a computer program. Data point locations for the Monitoring Station map (see Figure A-2) were described in terms of the site coordinates of the air pollution grid system, converted to inches.

2.1.5 Testing of Base Maps

The base maps were tested using representative census and air quality data. The Census Tract Map (Figure A-1) was tested at the scale of the Interstate Air Pollution Study Map (.15, or 15 percent, of the original source map size) and at the scale of a Census map (.10 of the source map size) which showed the outer boundary of the SMSA. The monitoring station map (Figure A-2) was also tested at the scale of the Interstate

Air Pollution Study Map.(13) Since actual air quality data were limited to locations in the central portion of the SMSA, several test maps were made to determine the final method of mapping these data: (i) data were extrapolated to the boundary of the SMSA; (ii) a barrier to interpolation was placed around the limits of the Interstate Air Pollution Grid Study Area; (iii) a limited search radius was used to define the extent of the mapped data.(14)

Since the monitoring stations are located only in the central portion of the SMSA, extrapolation of the data to the boundary obviously produces erroneous results. The tests also indicated that the mapping for the area within the limits of the Interstate Study Area was the same whether or not a barrier was used around the area. Therefore, area Otolegends--less expensive than using barriers--were used to cover the area beyond the limits of the Interstate Study Area. However, the use of either the barrier or the area Otolegends around the indicated area still tended to produce erroneous interpolations at the outer edges of the Interstate Study Area because of the broad extent of this area in relation to the clustering of stations in the central zone.

The use of a limited search radius(15) eliminated this problem and so it was utilized for the final air quality maps produced.

2.1.6 Map Levels and Symbolism

For the majority of the census and land use data--where the mapped values are in terms of percentages--five standard levels were used to describe the data. All of the density maps were made using "quintiles." Population density was also mapped using various specified intervals.

The quintile elective was used for the initial mapping of the air quality data, although in a few cases specified levels were used. The choice of intervals and number of levels for each map is, ideally, dependent on the specific purpose for which the map is to be used.

The intervals selected for mapping determine the initial impression the user receives from a particular map before he looks at the statistical details of the data. Distribution of the data into quintiles when mapping socio-economic data, for example, may give an impression of a more equal distribution of the data than actually exists. When mapping non-white population data, where only 15% of the census tracts have a non-white population of more than 20%, distribution of the data into quintiles gives a visual impression that the non-white population is distributed over a wide area. (The highest level ranges from 9.75% to 100% and accordingly is indicated by the highest value symbolism.) For this reason, the standard of five levels--with 20% of the values in each level--was generally used for this type of data.

In the case of data presented in terms of percentages, it might also be useful to specify a minimum of 0% and a maximum of 100% before distributing the data into levels. Distribution of the data into quintiles may make comparisons between maps a difficult process. Accordingly, division of the data into selected specified intervals can simplify this process.

The data point symbolism used varies according to the type of data mapped. For maps displaying population and housing data, the symbolism of the appropriate level was also used at the data point location. At the scale most often used in the study (.10 of the source map size), different symbolism would interfere with the reading of the mapped data; the location of data points in the central portion of the area may be as close as 1/10" from each other.

The location of the data point was generally designated with an asterisk on the air quality maps. A test was made to determine whether it was feasible to print the actual value at the location of each monitoring station. At the .10 scale, there was not sufficient space to do this in some cases. This would be possible, however, at a larger scale.

2.2.1 Air Pollution Data

The Interstate Air Pollution Study provided air quality, emission, and meteorological data for the period 1963 to 1965. This data was available in the printed reports of the study--as discussed in Section 1--and in computer readable form. The air quality and meteorological data were obtained on tape.(16) Emissions data were provided on cards.

The majority of the data analysis and mapping was done with the measured air quality data, particularly for the winter months of 1963-1964 and 1964-1965. This air quality data was the most extensive available for any region, providing a wide range of diurnal, daily, seasonal, and climatological variability for spatial display.

None of the emissions data was mapped directly since (i) the inventory was not complete and up-to-date, and (ii) better inventories could be mapped for other regions.(17) The emissions data were used in preliminary diffusion model calculations, together with the meteorological data. Because of the inadequacies of the input data and the time-consuming nature of developing and adapting advection-diffusion models, this work was later limited to a study of power plants in the St. Louis area covered in a separate report.(18)

Initially, air quality data was copied from the printed reports. When the data tapes became useable, computer programs were written to average and combine data for different time periods and meteorological conditions.

2.2.2 Socio-Economic Data

A large body of socio-economic data is available for comparison with air pollution data. It was first necessary to select those variables which might prove to have a strong relationship to air pollution. These variables moreover had to be selected in terms of the immediate objectives of this portion of the study:

i) to identify those segments of the population and environment affected by various levels of pollution; and,

ii) to identify patterns and combinations of patterns of data that correspond in statistical terms to a high level of pollution.

Census data provided the best source since the data are: (i) readily available in Census reports or on tape; (ii) readily transferred to punch card; and, (iii) collected in terms of census tracts which are spatially defined units.(19)

Three kinds of variables were selected: (i) population characteristics; (ii) housing characteristics; and, (iii) land use. The population variables included: population density, population per household, non-white population, median school years completed, family income, and age. The housing variables included: deteriorating and dilapidated units, housing units with 1.01 or more persons per room (a measure of overcrowding), age of housing, and number of units in structure. The land use variables included six types of land use.

The population characteristics selected serve as a basis for identifying the major segments of the population affected by air pollution. Population itself--in combination with other factors--is also a variable which affects the level of pollution. Housing is a variable which is affected by pollution; conversely, various types of housing contribute to pollution. Land use is an aspect of the environment that affects and is affected by pollution.

All of these variables can be analyzed in terms of their spatial patterns to test their relationships to air pollution patterns.

Since a tape of the 1960 Census data was not available at the time, selected variables from the Census Report were punched on cards to form a small data bank. Separate decks--and tapes--were created for population characteristics and for housing characteristics. The area of each census tract was measured with a planimeter and this information was added to the data bank so that densities could be computed.(20)

Land use data for the City of St. Louis were punched onto cards.(21) Computer programs were written to read the data from cards or tape and manipulate it so it could be mapped in the appropriate form.

3. MAPS PRODUCED IN THE STUDY

3.1 DIRECT MAPPING OF VARIABLES

Air quality maps were produced of the levels of sulfur dioxide and suspended particulates. Twenty-four hour concentrations of sulfur dioxide for two winter seasons were mapped. Maps of two-hour sulfur dioxide readings throughout the day were also produced. The level of suspended particulates for a fall season, a winter season, and for a one year period were mapped.

A series of maps was produced to describe the socio-economic structure of the area--total population and age-group population densities; percent families with low, middle, and higher incomes; percent housing units in deteriorating and dilapidated condition; percent non-white population, etc.

To determine the relationships between levels of pollution and demographic variables, comparisons and statistical correlations were made between the air quality data and the census data. A map of estimated sulfur dioxide values was produced from a regression equation based on population and housing variables. Maps were also made relating specified levels of sulfur dioxide pollution to population, age-group, and income densities. In addition, maps were made relating levels of sulfur dioxide and suspended particulates to population density.(22)

3.1.1 Land Use

The only land use data readily available in a form for mapping were for St. Louis City (see Figures A-3 and A-4). The mapped data indicate that the highest proportion of: (i) residential use occurs in the western half of the city; (ii) commercial use occurs in downtown St. Louis and extends roughly across and slightly above the mid-section of the city; (iii) industrial use occurs in a strip along the Mississippi River and in a strip across the mid-horizontal plane of the city below the commercial zone; and, (iv) vacant land occurs in the northern part of the city along the Mississippi, and near the southern tip of the city.(23)

3.1.2 Sulfur Dioxide

The maps indicate that the highest concentrations of SO_2 occurred in the downtown St. Louis area and extended across the river during both winter seasons. (See Figure A-5.) There was an increase in the level of SO_2 at these locations from the first winter to the second winter. The greatest absolute increases in the area during this period occurred in Illinois in the vicinity of Venice and Granite City, in a portion of East St. Louis, and in a portion of Centreville (see Figure A-6). There was very little difference in the maps of the arithmetic and geometric means.

The maps which used a greater number of monitoring stations (40 versus 19) indicated higher levels of SO_2 concentrations in the area west of St. Louis City and in the East St. Louis - Monsanto area than had been indicated when fewer stations were used (see Figure A-7).

The two-hour averages (see Figures B-1 to B-7) showed substantial fluctuation in the location of peak concentrations throughout the day. The highest concentrations appeared to move in a somewhat diagonal pattern from northwest to southeast, and back again. However, this movement was not consistent.(24)

3.1.3 Suspended Particulates

Maps for the fall of 1963, the winter of 1963-1964, and the entire period, July 1963-June 1964, were produced. These maps include the arithmetic and geometric means, and the minimum and maximum values recorded at each station (see Figures A-8 to A-13).

The largest peak concentration of particulates for the periods mapped occurred in the area of Venice and Granite City. A somewhat smaller peak occurred at the southern tip of St. Louis City and across the river from this area in Illinois. Another smaller peak occurred in the East St. Louis area. The minimum, maximum, geometric mean, and arithmetic mean maps varied somewhat as did the maps for each season. However, in spite of these variations, all maps indicated that the largest area of peak concentration was in the Venice - Granite City area.

3.1.4 Population and Housing Characteristics

The maps describe selected characteristics of the St. Louis Metropolitan Area in a generalized way. The SYMAP program assumes continuity of the data, and thus the maps depict the prevalent trends, as of 1960, within the area.

There are three basic patterns in the mapped data:

i) The first is the case where the highest, or peak, values occur in downtown St. Louis and at the location of various smaller cities--such as Alton, St. Charles, etc; the lowest values occur in the outlying or peripheral areas. All the density maps--population density (Figures B-9 and B-10), density of families with incomes under $3000 (Figure B-16), density of population under ten years of age (Figure B-27), density of population aged 65 and over (Figure B-26)--are of this type. The maps of percent housing units with more than one unit in structure (Figure B-20), percent housing units with more than 1.01 persons per room (Figure B-19), and percent non-white population (Figure B-14a), are also of this general type, but in a modified form.

ii) In the second type of pattern, a high peak occurs in the center of the area, the lowest values occur in the middle ring, and a rise in values generally occurs in the lowest density areas on the periphery. Maps of this type include: percent families with income less than $3000 (Figures B-14b and B-15), percent population aged 65 and over (Figure B-12), percent housing units built in 1939 or earlier (Figure B-23), and percent housing deteriorating and delapidated (Figure B-18).

iii) The third type of pattern exhibits the lowest values in the center, the highest values in the ring around the center, and lower values in the peripheral areas. Maps of this type include: percent housing units built 1940-1949 (Figure B-24), percent families with income $8000 and over (Figure B-17b), and median school years completed (Figure B-13). A number of other maps also represent this type in a somewhat modified form. These include: percent housing units built 1950-1960 (Figure B-25), population per household and percent population under age 10 (Figure B-11).

In all of these patterns, the boundary of the city of St. Louis often acts as a border between higher and lower values, though the border at times extends somewhat beyond the city itself. It is always apparent, however, that the character of the central areas--St. Louis, East St. Louis, and certain of the smaller cities--differs considerably from the character of the suburban areas or the peripheral zones. These inner areas have a greater population density, a greater density of poor, of aged people, and of children. They also contain the highest proportion of the poor and the aged, and most of the non-white population in the metropolitan area. In addition, they contain the highest proportion of old, dilapidated and deteriorating housing.

3.2 RELATIONSHIPS BETWEEN SOCIO-ECONOMIC AND AIR QUALITY DATA

The simplest way of relating air quality data and population or housing data is by means of overlays. Assuming that the maps are at the same scale and cover the same geographic area, a visual analysis of the relationships between two sets of data can be made. Each of the maps can also be used as an overlay for other kinds of mapped data--for example, air quality data can be related to topographic maps in this way.

This method is direct and immediate. Moreover, a wide range of analyses is possible if a set of maps is made by changing only the intervals used. A disadvantage of this kind of analysis is that overlays may at times be difficult to read, and detail may be lost. In addition, it does not take advantage of the computer techniques which permit combinations and manipulations of data to be made and mapped.

3.2.1 Comparison Mapping Technique

The SYMAP program does not permit direct comparisons of data collected on the basis of inconsistent data zones or of data based on different units of measurement. It can provide on tape--by the use of elective 21--the values of each character location for each map produced in the form of a matrix or x-y grid of values.(25) Two or more matrices of this kind can then be related by comparing the value in one matrix with the value at the same location in another matrix. It is assumed that the original maps were produced at the same scale and for the same designated area.

If the values have similar units of measurement, the data can then be manipulated directly--by addition, subtraction, etc. --to achieve the desired result. Otherwise, the sets of data can be compared subjectively in terms of logical relationships--using critical or "threshold" levels as the basis for comparison.

Comparison maps typically use very few levels. For example, level one might represent that part of the region in which both sulfur dioxide concentrations and population density were higher than certain standards or thresholds. Level four might represent the areas where both variables were lower than the thresholds. Levels two and three would then describe those areas where one or the other variable exceeded the threshold. A possible disadvantage of this method is that data must relate to specified levels. For air quality data, this presents no apparent difficulty, since the level chosen can be a specified standard. However, for other kinds of data there may be no critical level. Since the analysis is dependent on a chosen level, the mean might in this case serve as a useful threshold. The use of a series of maps using different levels as a basis for comparison can also obviate this problem.

By using this comparison technique, the intersection of two or more sets of data can be described and analyzed. The resulting values for each character location--whether quantitatively or subjectively determined--are stored on tape and mapped using the GRID program, which is designed for mapping data already in a grid or matrix form.(26)

3.2.2 Regression Analysis Technique

Regression analysis was employed to test the similarity of the surfaces for the pollution and population and housing data. All relevant maps for this purpose were produced at a 9" x 10" size and the matrix of values for each character location for each map was printed. The values at the locations of the monitoring stations were then used in the regression analysis between the pollution data and eighteen population and housing variables. It should be noted that since these stations are located only in the central, urbanized portion of the metropolitan area, the statistical analysis is only valid for this area.

3.2.3 Comparison Mapping Results(27)

A series of maps (Figures A-14 to A-16) was made relating levels of sulfur dioxide to each of three variables: population density, density of population aged 65 and over, and density of population under age 10. Two threshold levels of SO_2 (. 03 and . 04 ppm) were related to the averages for the density data to demonstrate the intersection of the two sets of information. The resulting maps proved to be quite similar in overall patterns, but differed in detail. When a threshold level of . 03 ppm was used, the area affected by this level, or a higher level--in other words, the area which had a density equal to or above the mean of the specified density variable--included East St. Louis, Granite City, most of the city of St. Louis, and an area extending somewhat beyond the city to the west. When a threshold level of . 04 ppm was used, the area affected by this level or higher included East St. Louis and the center and southwest portions of the city of St. Louis,

Comparison maps (Figure A-17) were also produced relating a specified level of SO_2 (. 04 ppm) and specified levels of suspended particulates (75 and 120 μ/m^3) to the mean of the population density. The area of intersection of these three sets of data included the downtown section of St. Louis and the area adjacent to it.(28) When the level of particulates was changed from 75 to 120, there was only a slight difference between the maps indicating that all of the area described--except for a small section in the northwest corner--was affected by a level of 120 or higher.

It appears that the highest levels of sulfur dioxide occur--and presumably have the greatest impact--in the areas where:

i) the highest density of population occurs;

ii) the greatest density and proportion of the aged live;

iii) the greatest density of children exists;

iv) the greatest proportion of the non-white population lives; and

v) the greatest density and proportion of the poor are.

In terms of this particular pollutant, it is apparent that the character of the central and core areas differs considerably from that of the suburbs and peripheral areas. A contributing factor in this case is likely to be the tendency for the proportion and number of housing units heated with coal or oil to be higher in the older and poorer areas. In addition, the location of various industries which use substantial amounts of coal and oil may be an important factor.

The relationships between suspended particulates and socio-economic characteristics, however, are not clear. This type of pollutant may well be more closely related to land use and land use activities than to demographic variables such as population and housing.

3.2.4 Regression Analysis Results

In terms of simple correlation, percent families with incomes less than $3000, and percent housing units deteriorating and dilapidated, had the highest correlation with sulfur dioxide concentrations--0.768 and 0.740, respectively. Multiple regression indicated that four or five variables in combination--percent families with incomes less than $3000, percent nonwhite population, percent housing units deteriorating and dilapidated, percent population aged 65 and over, and percent population under 10 years of age--best described the surface of the SO_2 data. A map of estimated sulfur dioxide values for winter 1964-1965 was produced from a regression equation based on this analysis of the population and housing variables (See Figure B-8).

There appeared to be no strong correlation between the population-housing variables and suspended particulates data tested.(29)

3.2.5 Applications

The method of approach used here is equally applicable to other metropolitan areas or to smaller or larger regions. The principal limitation in practice is perhaps the availability of adequate data. For the St. Louis Project, air quality data for 1963-1965 were related to Census data for 1960. The need for current data as well as for time series data for all the variables is obvious. The need for actual air quality data for a broader region, or some means for estimating such data, is also evident. In addition, the availability of land use data in a suitable form would be extremely useful.

The techniques described here may be employed to describe a broad range of surfaces and relationships pertaining to air pollution. The possibilities are in fact infinite. In addition to the simple mapping of all types of pollutants and a wide variety of socio-economic or other indices, it is possible to determine relationships between various types of pollutants as well as relationships between one or more pollutants and one or more socio-economic variables.

More complex manipulations can also be made. For example, the level of pollution can be related to the level of housing deterioration. Cost can then be assigned on the basis of certain assumptions, and a total "pollution cost" derived.

The techniques described can serve as useful tools to assist in planning for the quality of the urban environment. Alternative schemes concerned with changes in land use or population densities and with reduction of pollution at the source can be tested to determine their long range impact on the area in terms of pollution. Planning decisions can then be based on air quality as well as other factors. The relationship between air pollution and socio-economic variables can also be studied for a number of metropolitan areas as a means of constructing a model of the pollution surface to supplement traditional diffusion model approaches.

REFERENCES

(1) This background section was adapted from the St. Louis - East St. Louis Interstate Air Pollution Study, Phase II Project Report, DHEW, USPHS, Division of Air Pollution, Technical Assistance Branch, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio, May 1966.

- I. Introduction
- II. Air Pollutant Emission Inventory
- III. Air Quality Measurements
- IV. Odors - Results of Surveys
- V. Meteorology and Topography
- VI. Effects of Air Pollution
- VII. Opinion Surveys and Air Quality Statistical Relationships
- VIII. A Proposal for an Air Resource Management Program

(2) *Ibid*, Report II.

"Emission factors in this report were prepared after a thorough investigation of previous work by personnel of the Technical Assistance Branch, Division of Air Pollution," p. 41.

(3) 4.5 pounds per capita per day of which 75 percent was combustible--these per capita averages were based on the results of past studies in 12 cities conducted by the American Public Works Association.

(4) Mayer, M., *A Compilation of Emission Factors for Combustion Process Gasoline Evaporation and Selected Industrial Processes*, Technical Report, Division of Air Pollution, R. A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio, May 1965.

(5) Interstate Air Pollution Study, *op. cit.*, Report III, p. 5.

(6) The 7.5 minute series (1:24,000, or 1" = 2000') was used where available. In several instances, when this series was not available, the 15 minute series (1:62,500) was used.

(7) Latitude and longitude were defined for the 7.5 minute series as follows: latitude, 1 minute = 3.027 inches; longitude, 1 minute = 2.377 inches. The grid coordinate measurements were defined as follows: length of the side of one grid cell = 10 units, or 5 inches; 1 unit = .5" (or 1000 feet).

(8) Thus, a map was designed in which the outline represented a range of 39°00'00" to 38°00'00" latitude and 90°52'30" to 89°40'40" longitude. These ranges produced a map size of 181.6" (vertical) and 170.7" (horizontal).

(9) The outline of the Monitoring Station map represented coordinates extending from 820 to 560 (thousand feet) on the vertical axis and from 390 to 590 on the horizontal axis. This yielded a map size of 130" (vertical) and 100" (horizontal). The outline of this map was also enlarged to coincide with the limits of the census tract map; in this version, the coordinates extended from approximately 850 to 490 on the vertical axis and from approximately 300 to 640 on the horizontal axis.

(10) The 7.5 minute series U.S.G.S. topographic maps; latitude and longitude were converted to measurements in inches in relation to the (0., 0.) point by means of a computer program.

The maps which delineated the boundaries of the SMSA somewhat exceeded the limits of the rectangular outline maps, extending 201.6" in the vertical dimension and 225.3" in the horizontal dimension.

(11) The tick marks and river Otolegends were converted from latitude and longitude locations and grid coordinate locations to inches by computer programs.

(12) In checking the location of the centers of tracts as defined by the Bureau of the Census, it was determined that a number of these locations were incorrect--the location as defined in terms of latitude and longitude was not in the approximate center of the tract. Changes were accordingly made in the latitude-longitude designations to approximate centers of tracts where it appeared that an error had been made.

(13) Selected portions of the census tract map were also tested at the scale of the 15 minute series U.S.G.S. maps (.384 of the source map) and at the scale of the Census map which depicted St. Louis City (.36 of the source map). The map shown in Figure A-2 was tested using air quality data from Volume III of the Interstate Study Report.

(14) The problems of missing data near the periphery of the study area--and the solutions mentioned--are discussed in the report on the Kansas City Region Study, Volume Two, Report D.

(15) In this case, the search radius was limited to 15 source map units, or 30,000 feet.

(16) The data was provided on a Honeywell tape by Jerry Mersch of NAPCA. Very substantial unforeseen difficulties were encountered in unpacking and transposing this data to tapes compatible with the IBM equipment at the Harvard Computer Center. Because of these difficulties, it is strongly recommended that in the air pollution field:

- i) data be provided by one group to another in card form so that the problems of deciphering incompatible tapes can be avoided; and,
- ii) long term proposals for data handling include considerations of data storage, analysis, and transmittal compatibilities.

(17) Kansas City (Volume Two, Report D), Boston (Volume Two, Report J), and--for projected emissions--Puget Sound (Volume Two, Report H).

(18) See Volume Two, Report C. The preliminary modeling done for the St. Louis area as a whole was inconclusive and is not presented here.

(19) When the study was started, it was assumed that other kinds of data--such as land use--could be obtained from some other source in a useable form, if needed. The primary emphasis was on the main body of census data.

(20) The Census data banks do not include information on areas of census tracts, necessitating a great deal of extra work to derive densities. In some cases, the areas were estimated, based on similar size tracts which had been measured.

(21) This was the only land use data available for the SMSA which was in a form that could be readily used for mapping.

(22) For convenience in use, for consistency in presentation, and in order to keep computer costs to a reasonable level, the following sizes of maps were produced:

i) Entire SMSA

.10 of the source map, 1" = 20,000

Vertical dimension - approximately 20 1/4"

Horizontal dimension - approximately 22 1/2", two panels wide

This is the smallest size at which superimposed data points do not occur in Figure A-1 and is the size which was useful for mapping census data.

ii) Entire SMSA

.044 of the source map, 1" = approximately 45,000'

Vertical dimension - 9"

Horizontal dimension - 10"

This size map is not large enough to present the data adequately, but was prepared principally to obtain the values for each character location, to be used in regression analysis and to be used in the GRID program to indicate relationships between air quality data and population and housing data. These values are also used to make SYMVU's. This size map is also useful as a general and quick source of reference when more detailed mapping is not required.

iii) Interstate Study Grid Area

.10 of source map, 1" = 20,000'

Vertical dimension - 12.5"

Horizontal dimension - 10"

This size represents the approximate units of the Interstate Study area and was especially useful for the air quality data and for SYMVU's.

(23) The source of the data mapped is the St. Louis City Plan Commission - 1963, St. Louis Land Use Statistics (1960). Data are in acres for each land use, by census tract.

(24) All figures with the reference "B" will be found in Appendix 1 of Volume Two, Report B, St. Louis Region Study--Part II.

(25) Each character location measures 1/8" x 1/10" on the output map. A discussion of this elective is found in Volume Two, Report K, Section 3, and of the use of the elective for map combinations in Volume Two, Report D, Section 2 and Appendix 3.

(26) The GRID program was developed by David F. Sinton at the Laboratory for Computer Graphics and Spatial Analysis and is a simplified version of SYMAP. See Volume Two, Report D, Appendix 5 for a brief discussion of the program as used in the Kansas City Region Study.

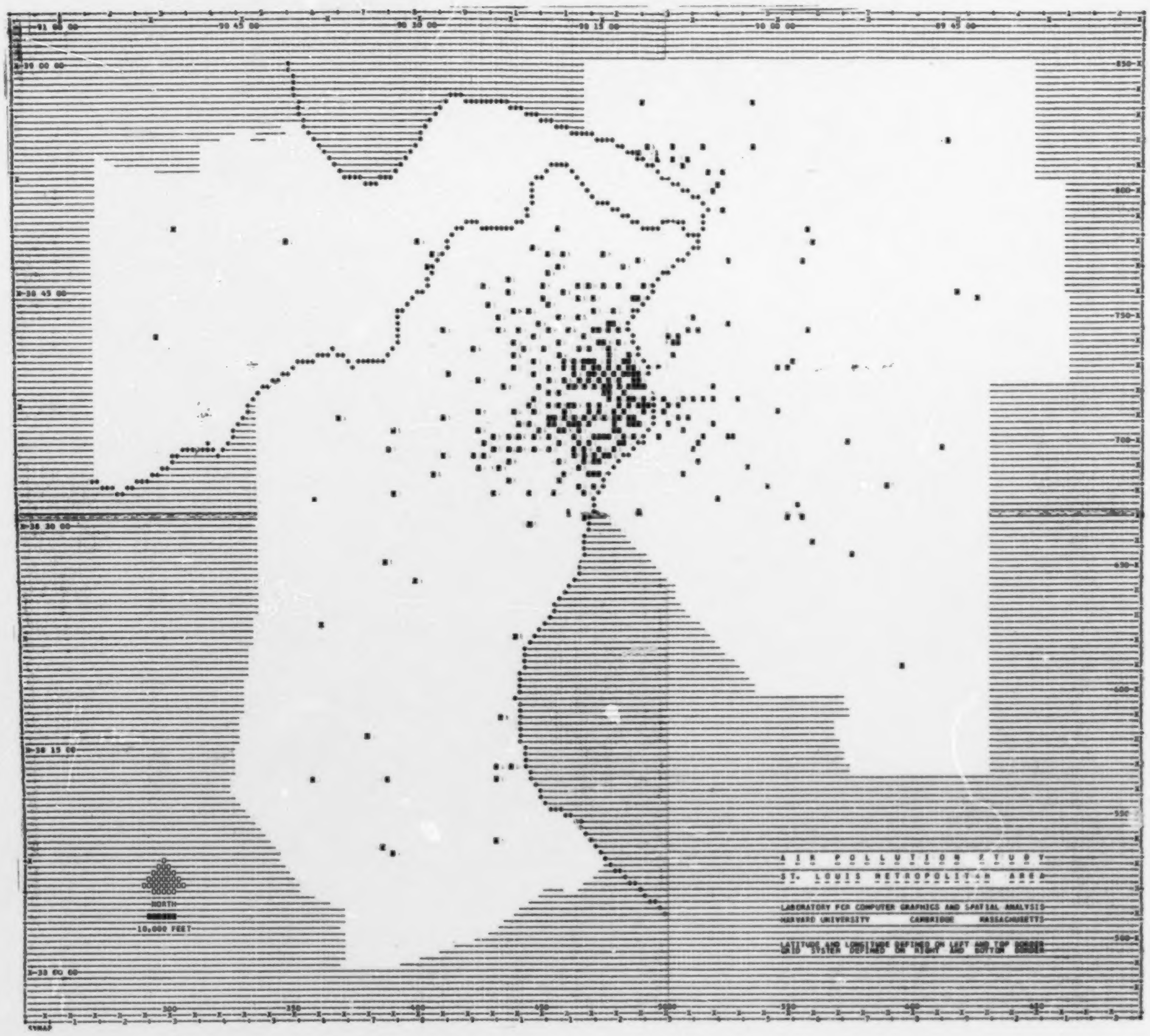
(27) Since pollution data were available only for the central portion of the metropolitan area, the comparison maps were produced only for this area, extending approximately from the coordinates 765 to 675 in the vertical direction, and from 440 to 540 in the horizontal direction, an area of about 300 square miles.

(28) Roughly between the coordinates 730 and 700 in the vertical direction and between 480 and 500 in the horizontal direction.

(29) A more complete discussion of the regression analysis will be found in Volume Two, Report B, St. Louis Region Study--Part II.

APPENDIX

COMPUTER GRAPHICS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90 15 00
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N-38 00 00
850
800
750
700
650
600
550
500
300
350
400
450
500
550
600
650
NORTH
10,000 FEET
AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE MASSACHUSETTS
LATITUDE AND LONGITUDE DEFINED ON LEFT AND TOP BORDER
GRID SYSTEM DEFINED ON RIGHT AND BOTTOM BORDER
SYMAP

```
C     ST.LOUIS STANDARD METROPOLITAN STATISTICAL AREA (1960)
C     CENSUS TRACTS


                                   CENTERS OF CENSUS TRACTS DEFINED ACCORDING TO U. S. CENSUS
                                     DEFINITION IN TERMS OF LATITUDE AND LONGITUDE

DATA VALUE EXTREMES ARE          0.00        0.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.00
  MAXIMUM      0.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           100.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1
          ----------

  SYMBOLS      ■
          ----------
  FREQ.      344
```

FIGURE A-1

ST. LOUIS REGION STUDY
Standard Metropolitan Statistical Area — 1960 Census
Census Tract Centers

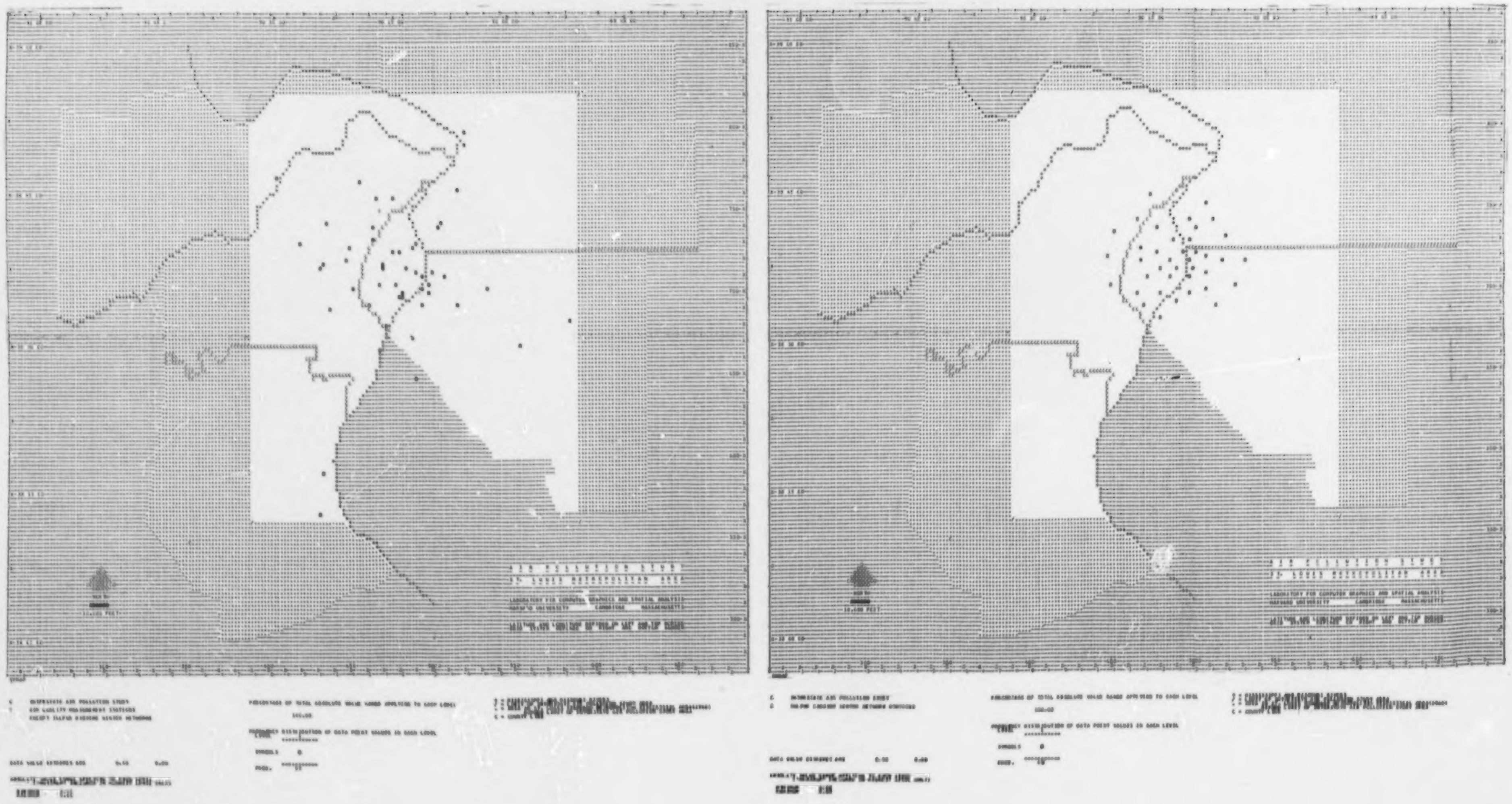
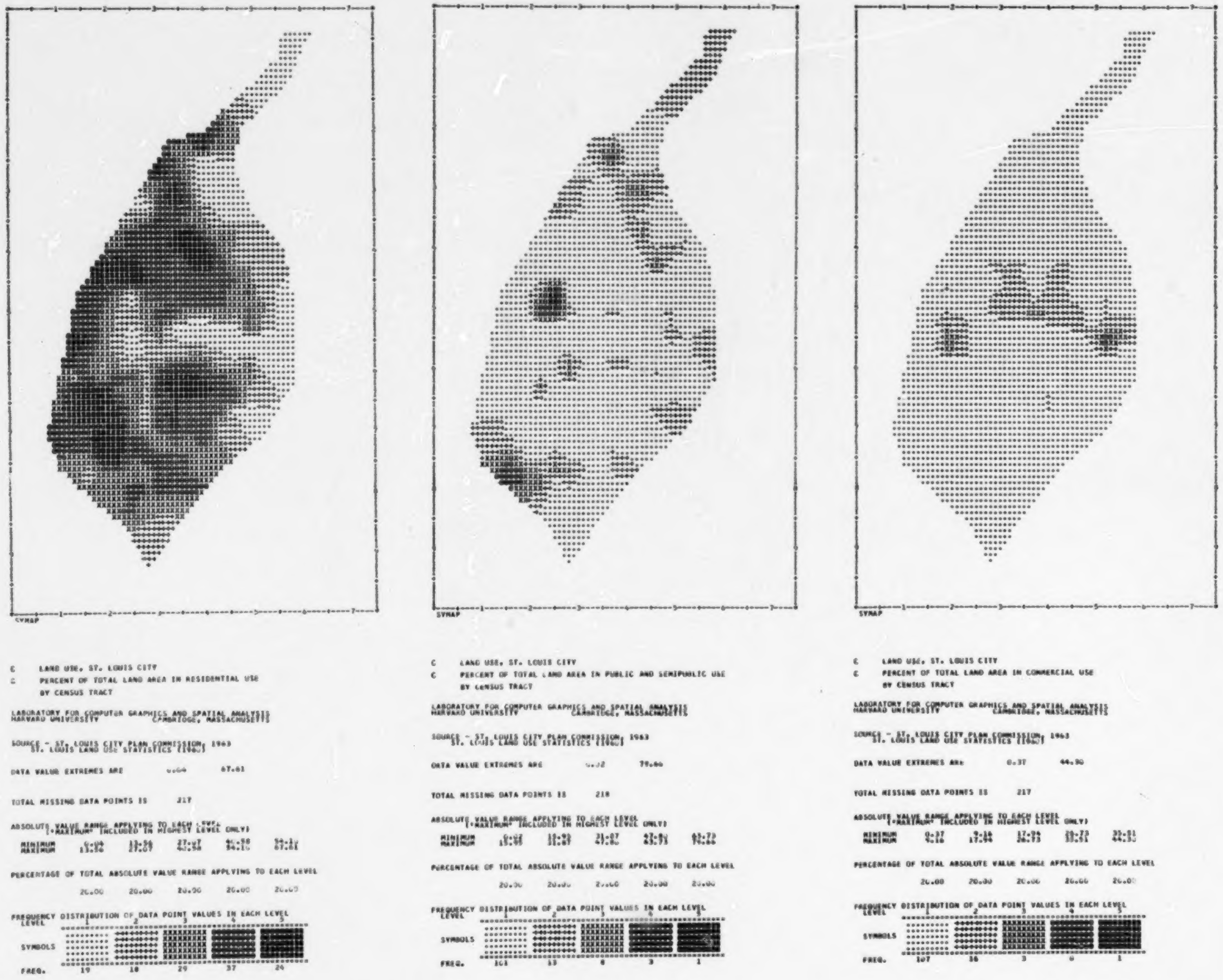


FIGURE A-2

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Measurement Stations — Winter Network — 1963-64
a. Except Sulfur Dioxide b. Sulfur Dioxide



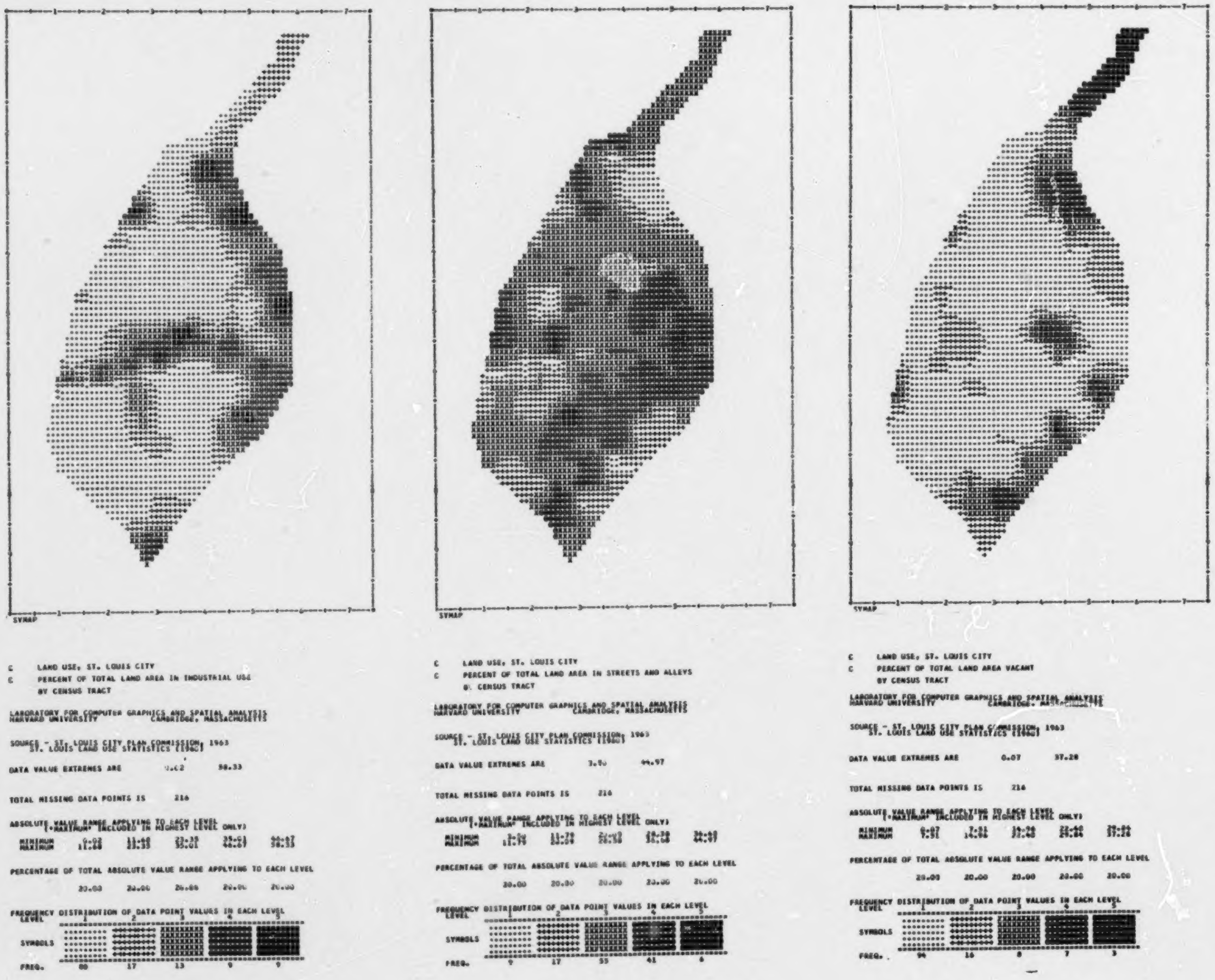
```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA IN RESIDENTIAL USE
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY          CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1962)

DATA VALUE EXTREMES ARE          0.04        67.61

TOTAL MISSING DATA POINTS IS      217

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       0.04      13.56      27.07      40.58      54.10
  MAXIMUM      13.56      27.07      40.58      54.10      67.61

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5

  SYMBOLS

  FREQ.         19         18         29         37         24
```

```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA IN PUBLIC AND SEMIPUBLIC USE
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY          CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1962)

DATA VALUE EXTREMES ARE          0.02        79.66

TOTAL MISSING DATA POINTS IS      218

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       0.02      15.95      31.87      47.80      63.73
  MAXIMUM      15.95      31.87      47.80      63.73      79.66

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5

  SYMBOLS

  FREQ.        161         13          8          3          1
```

```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA IN COMMERCIAL USE
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY          CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1962)

DATA VALUE EXTREMES ARE          0.37        44.30

TOTAL MISSING DATA POINTS IS      217

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       0.37       9.16      17.94      26.73      35.51
  MAXIMUM       9.16      17.94      26.73      35.51      44.30

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5

  SYMBOLS

  FREQ.        107         16          3          0          1
```

FIGURE A-3

ST. LOUIS REGION STUDY
St. Louis City — Land Use Maps
a. Percent Land Area in Residential Use
b. Percent Land Area in Public and Semipublic Use
c. Percent of Land Area in Commercial Use



```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA IN INDUSTRIAL USE
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY           CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1960)

DATA VALUE EXTREMES ARE          0.02       58.33

TOTAL MISSING DATA POINTS IS       216

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       0.02      11.68      23.35      35.01      46.67
  MAXIMUM      11.68      23.35      35.01      46.67      58.33

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
  SYMBOLS
  FREQ.         80         17         13          9          9
```

```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA IN STREETS AND ALLEYS
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY           CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1960)

DATA VALUE EXTREMES ARE          3.90       64.97

TOTAL MISSING DATA POINTS IS       216

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       3.90      [illegible]  [illegible]  [illegible]  [illegible]
  MAXIMUM      [illegible]  [illegible]  [illegible]  [illegible]  64.97

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
  SYMBOLS
  FREQ.          9         17         55         41          6
```

```
C     LAND USE, ST. LOUIS CITY
C     PERCENT OF TOTAL LAND AREA VACANT
      BY CENSUS TRACT

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY           CAMBRIDGE, MASSACHUSETTS

SOURCE - ST. LOUIS CITY PLAN COMMISSION, 1963
    ST. LOUIS LAND USE STATISTICS (1960)

DATA VALUE EXTREMES ARE          0.07       37.28

TOTAL MISSING DATA POINTS IS       216

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       0.07       7.51      14.94      22.40      29.84
  MAXIMUM       7.51      14.94      22.40      29.84      37.28

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               20.00      20.00      20.00      20.00      20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
  SYMBOLS
  FREQ.         94         16          8          7          3
```

FIGURE A-4

ST. LOUIS REGION STUDY
St. Louis City — Land Use Maps
a. Percent Land Area in Industrial Use
b. Percent Land Area in Streets and Alleys
c. Percent Land Area Vacant

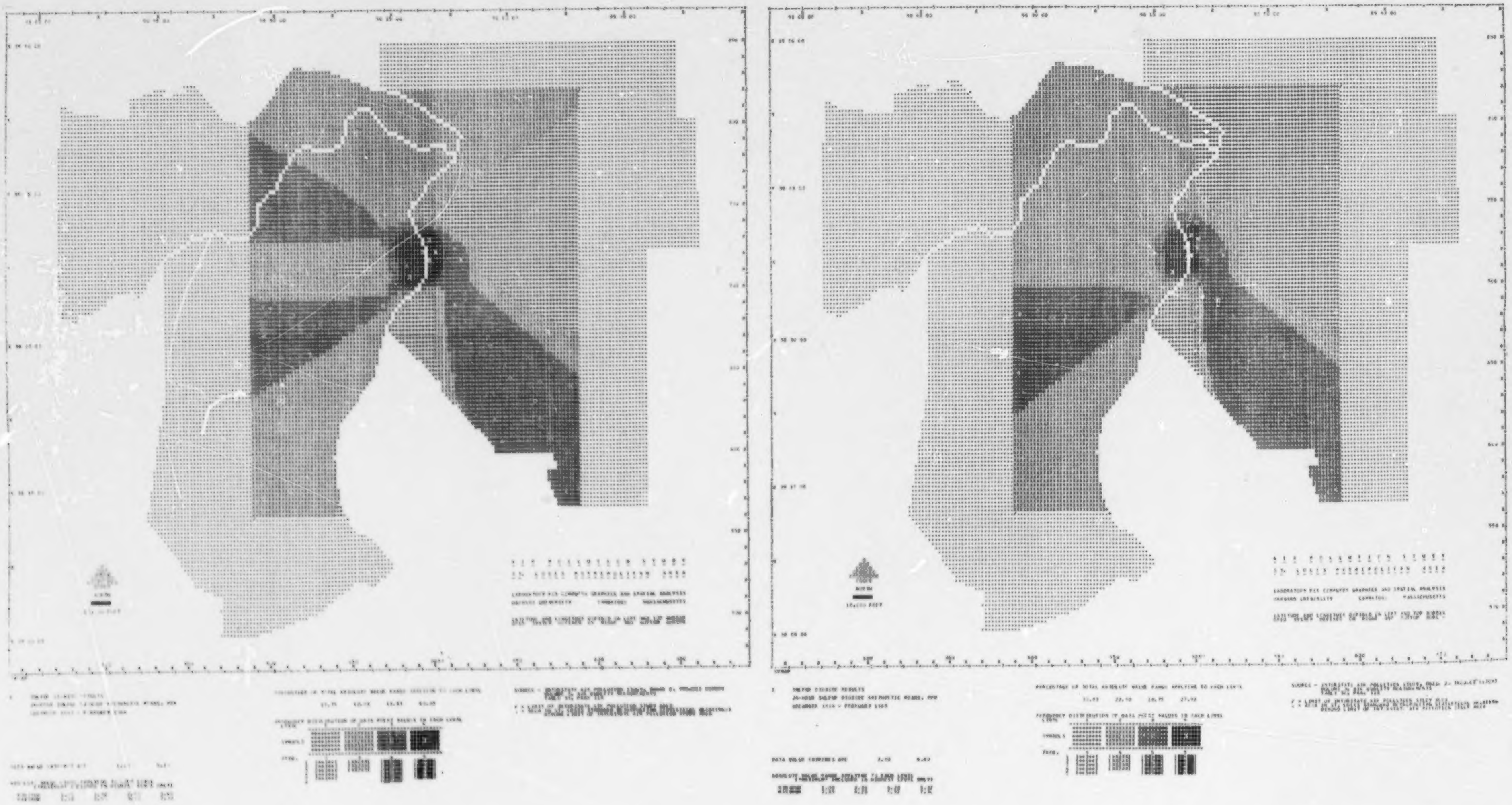
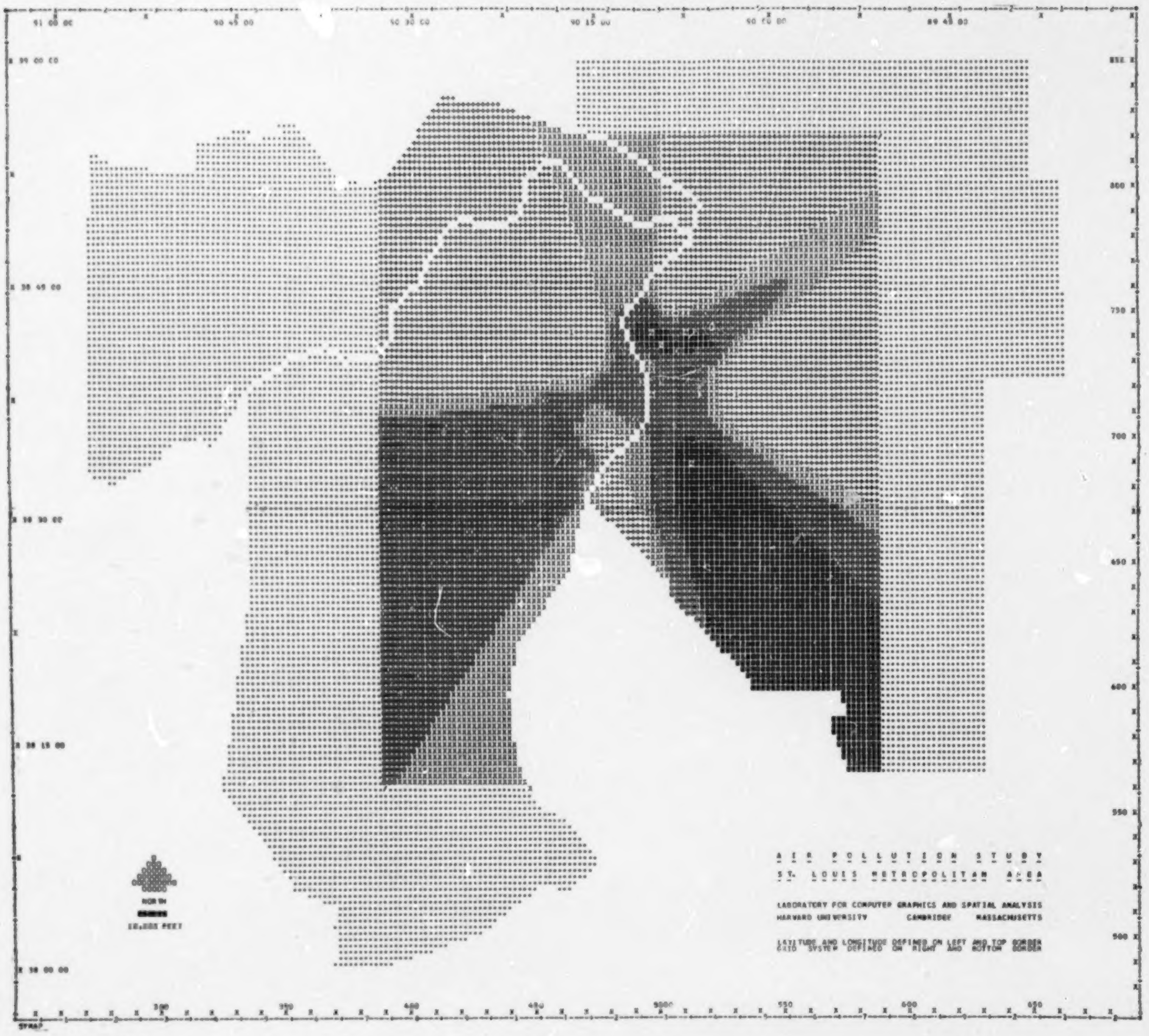


FIGURE A-5

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
24-hour SO_2 Readings — 19-Station Network
a. Arithmetic Means, Winter 1963-64
b. Arithmetic Means, Winter 1964-65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38 00 00
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750
700
650
600
550
500
300
350
400
450
500
550
600
650
NORTH
10,000 FEET
AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE MASSACHUSETTS
LATITUDE AND LONGITUDE DEFINED ON LEFT AND TOP BORDER
GRID SYSTEM DEFINED ON RIGHT AND BOTTOM BORDER
SYMAP

SULFUR DIOXIDE RESULTS
24-HOUR SULFUR DIOXIDE ARITHMETIC MEANS, PPM
DIFFERENCE (1964-1965 - 1965-1966)

SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
VOLUME 3, AIR QUALITY MEASUREMENTS
TABLE 30, PAGE 118

/ = LIMIT OF INTERSTATE AIR POLLUTION STUDY AREA
. = AREA IN ST. LOUIS STANDARD METROPOLITAN STATISTICAL AREA(1960)
BEYOND LIMIT OF INTERSTATE AIR POLLUTION STUDY AREA

DATA VALUE EXTREMES ARE 0.20 2.40

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	[illegible]	1.30	2.02
MAXIMUM	[illegible]	[illegible]	[illegible]	2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

39.98	14.98	30.21	15.63

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

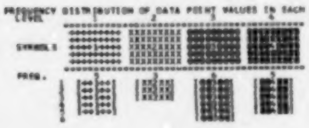


FIGURE A-6

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Differences between A-5a. and b.

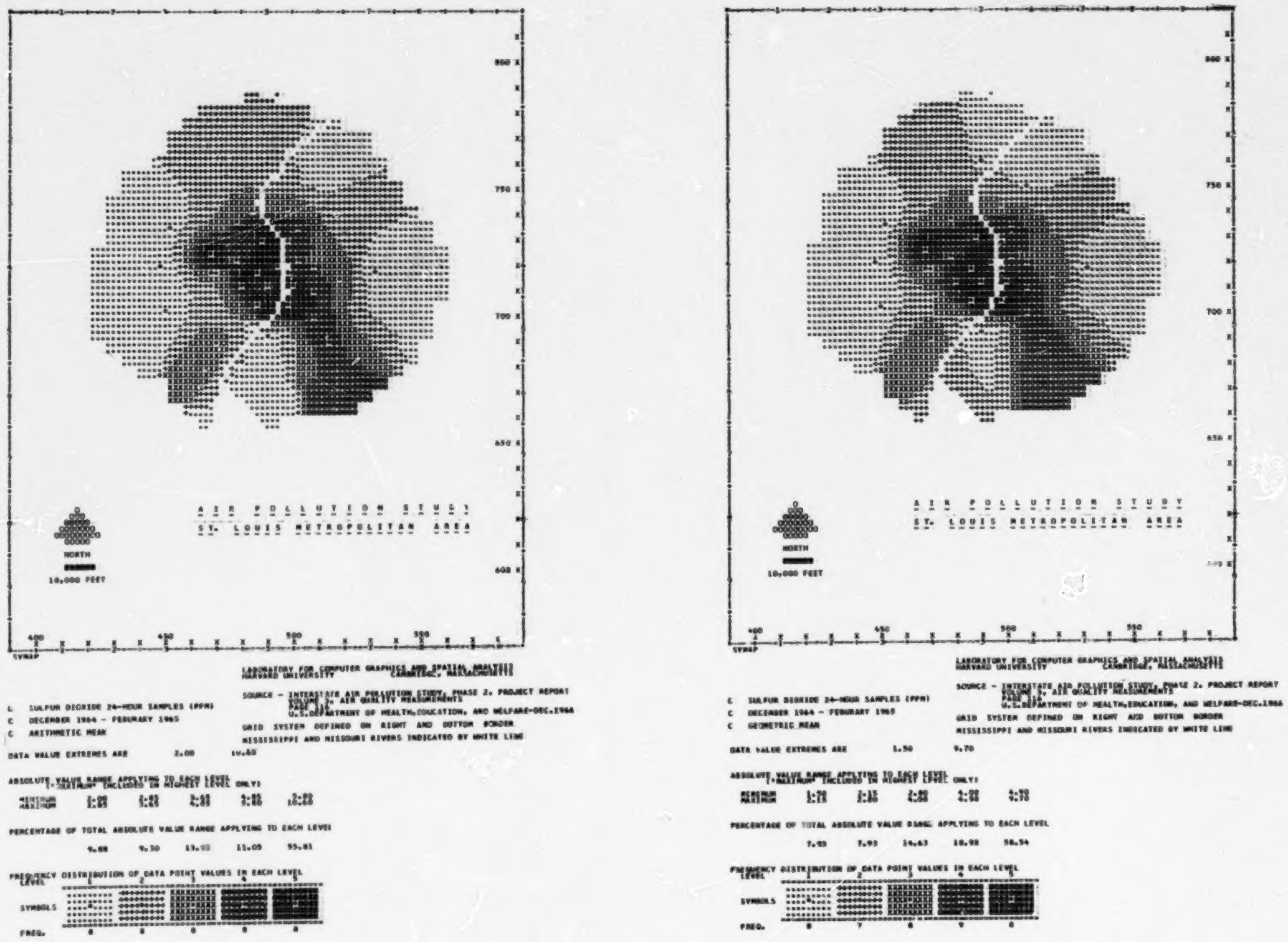
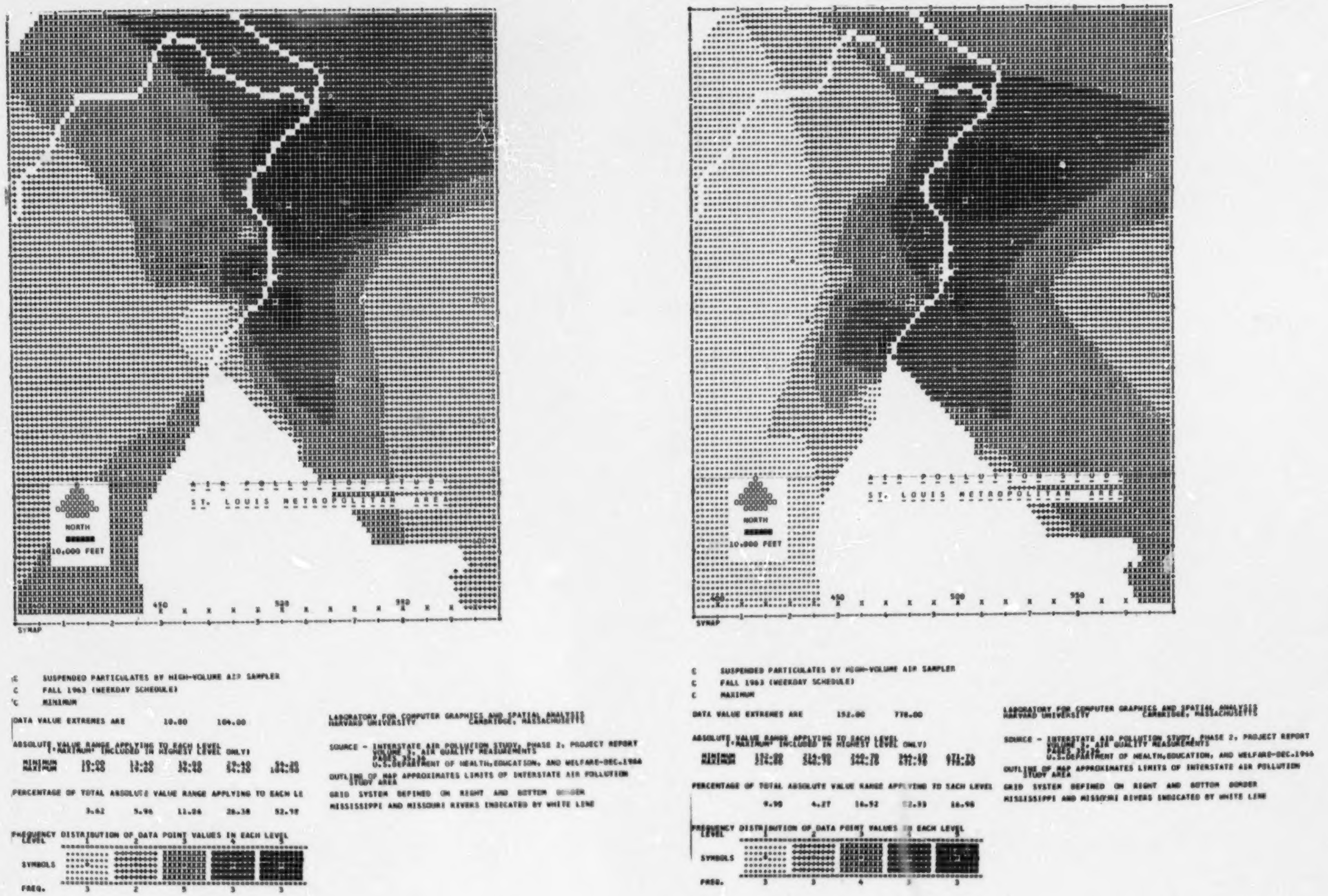

AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
NORTH
10,000 FEET
400
450
500
550
600
650
700
750
800
SYMAP
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS
SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
VOLUME 3, AIR QUALITY MEASUREMENTS
U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
GRID SYSTEM DEFINED ON RIGHT AND BOTTOM BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
SULFUR DIOXIDE 24-HOUR SAMPLES (PPM)
DECEMBER 1964 - FEBRUARY 1965
ARITHMETIC MEAN
GEOMETRIC MEAN
DATA VALUE EXTREMES ARE 2.00
DATA VALUE EXTREMES ARE 1.50 9.70
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
MINIMUM
MAXIMUM
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
9.10 11.05 55.81
7.93 7.93 14.63 10.98 58.54
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL 1 2 3 4 5
SYMBOLS
FREQ.

FIGURE A-7

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
24-hour SO_2 Readings — 40-Station Network
a. Arithmetic Means — Winter 1964-65
b. Geometric Means — Winter 1964-65



```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     FALL 1963 (WEEKDAY SCHEDULE)
C     MINIMUM

DATA VALUE EXTREMES ARE       10.00     104.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
    ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM     10.00    13.40    19.00    29.40    56.08
  MAXIMUM     13.40    19.00    29.40    56.08   104.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LE
              3.62     5.96    11.06    28.38    52.98

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL          1        2        3        4        5
SYMBOLS
FREQ.          3        2        5        3        3

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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     FALL 1963 (WEEKDAY SCHEDULE)
C     MAXIMUM

DATA VALUE EXTREMES ARE      152.00     778.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
    ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM    152.00   214.00   240.78   344.18   671.75
  MAXIMUM    214.00   240.78   344.18   671.75   778.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
              9.90     4.27    16.52    52.33    16.98

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL          1        2        3        4        5
SYMBOLS
FREQ.          3        3        4        3        3

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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
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         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```
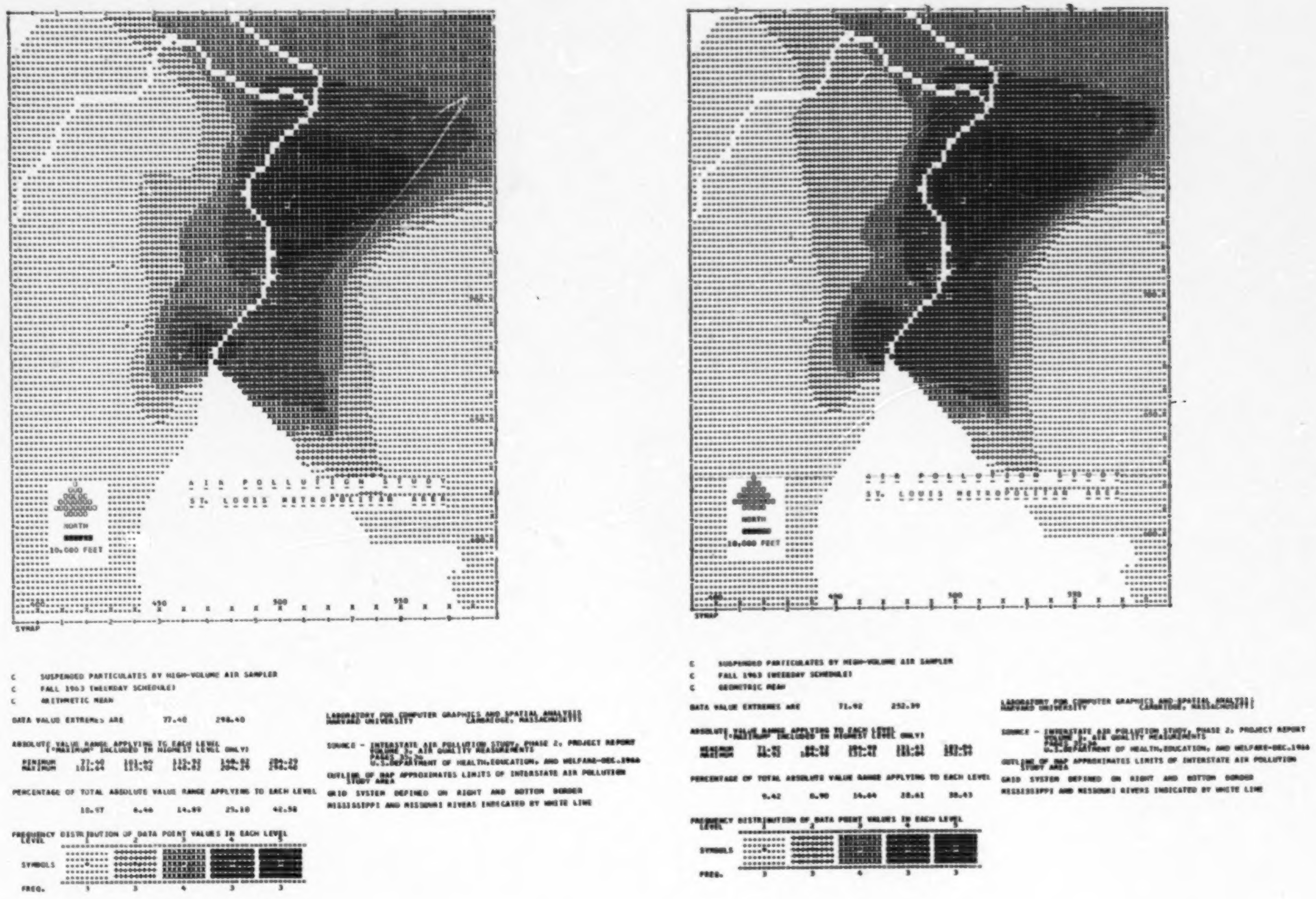

FIGURE A-8

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
Fall 1963 (Weekday Schedule)

a. Minimum b. Maximum



C SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C FALL 1963 (WEEKDAY SCHEDULE)
C ARITHMETIC MEAN

DATA VALUE EXTREMES ARE 77.40 298.40

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM [illegible]
MAXIMUM [illegible]

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.97 6.46 14.89 25.10 42.58

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	░	▒	▓	█	█
FREQ.	1	3	4	3	3

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HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS

SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
VOLUME 2, AIR QUALITY MEASUREMENTS
[illegible]
U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966

OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION STUDY AREA

GRID SYSTEM DEFINED ON RIGHT AND BOTTOM BORDER

MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE

C SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C FALL 1963 (WEEKDAY SCHEDULE)
C GEOMETRIC MEAN

DATA VALUE EXTREMES ARE 71.92 252.39

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM [illegible]
MAXIMUM [illegible]

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

9.42 6.90 14.64 28.61 38.43

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	░	▒	▓	█	█
FREQ.	3	3	4	3	3

LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS

SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
VOLUME 2, AIR QUALITY MEASUREMENTS
[illegible]
U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966

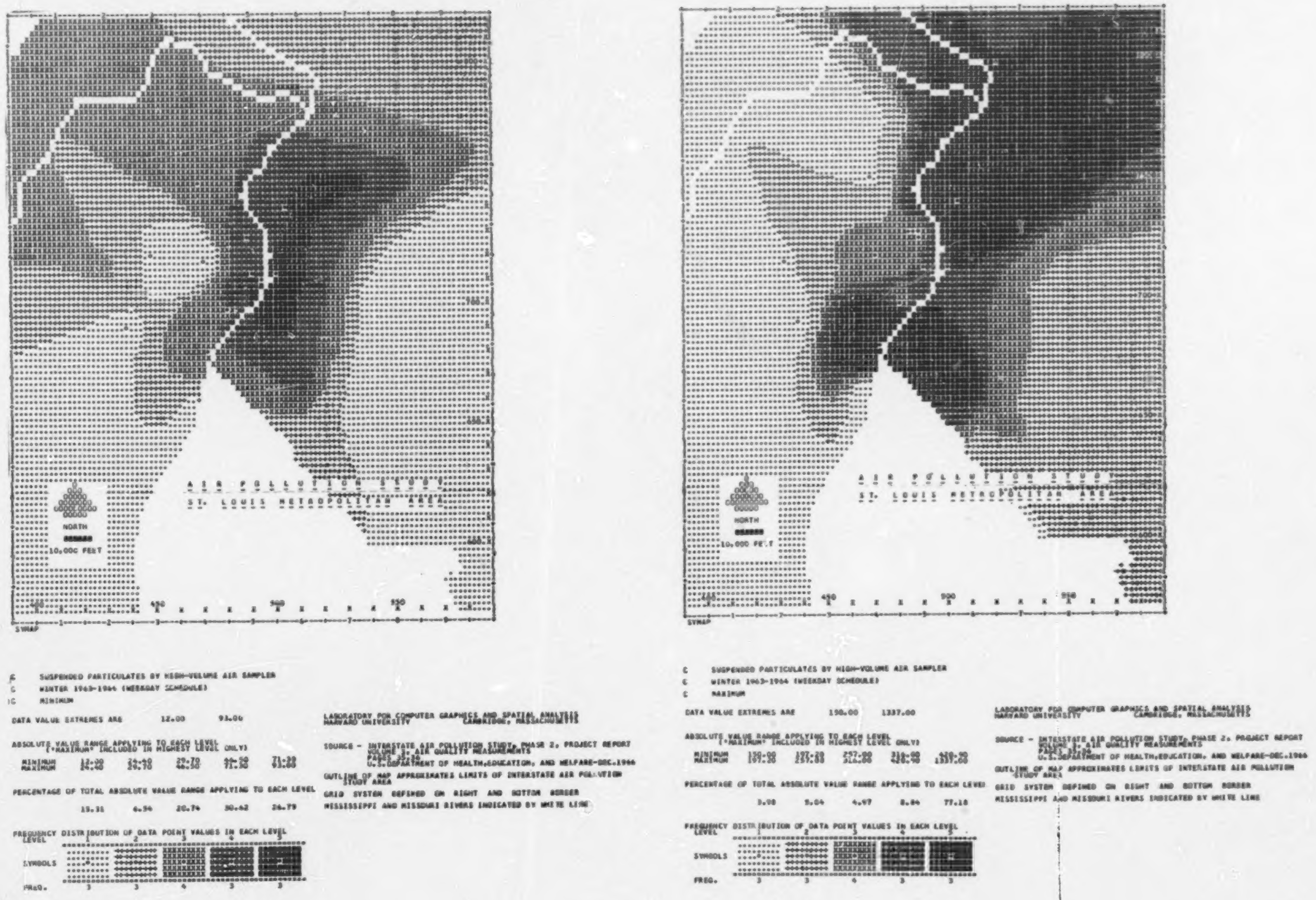
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION STUDY AREA

GRID SYSTEM DEFINED ON RIGHT AND BOTTOM BORDER

MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE

FIGURE A-9

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
Fall 1963 (Weekday Schedule)
a. Arithmetic Mean b. Geometric Mean



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C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     WINTER 1963-1964 (WEEKDAY SCHEDULE)
C     MINIMUM

DATA VALUE EXTREMES ARE        12.00      93.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      12.00    24.40    29.70    46.50    71.30
  MAXIMUM      24.40    29.70    46.50    71.30    93.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               15.31     6.54    20.74    30.62    26.79

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1        2        3        4        5
  SYMBOLS
  FREQ.          3        3        4        3        3
```

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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966

OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA

GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER

MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     WINTER 1963-1964 (WEEKDAY SCHEDULE)
C     MAXIMUM

DATA VALUE EXTREMES ARE       150.00    1337.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     150.00   197.20   257.00   316.00   420.90
  MAXIMUM     197.20   257.00   316.00   420.90  1337.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                3.98     5.04     4.97     8.84    77.18

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1        2        3        4        5
  SYMBOLS
  FREQ.          3        3        4        3        3
```

```
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966

OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA

GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER

MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```
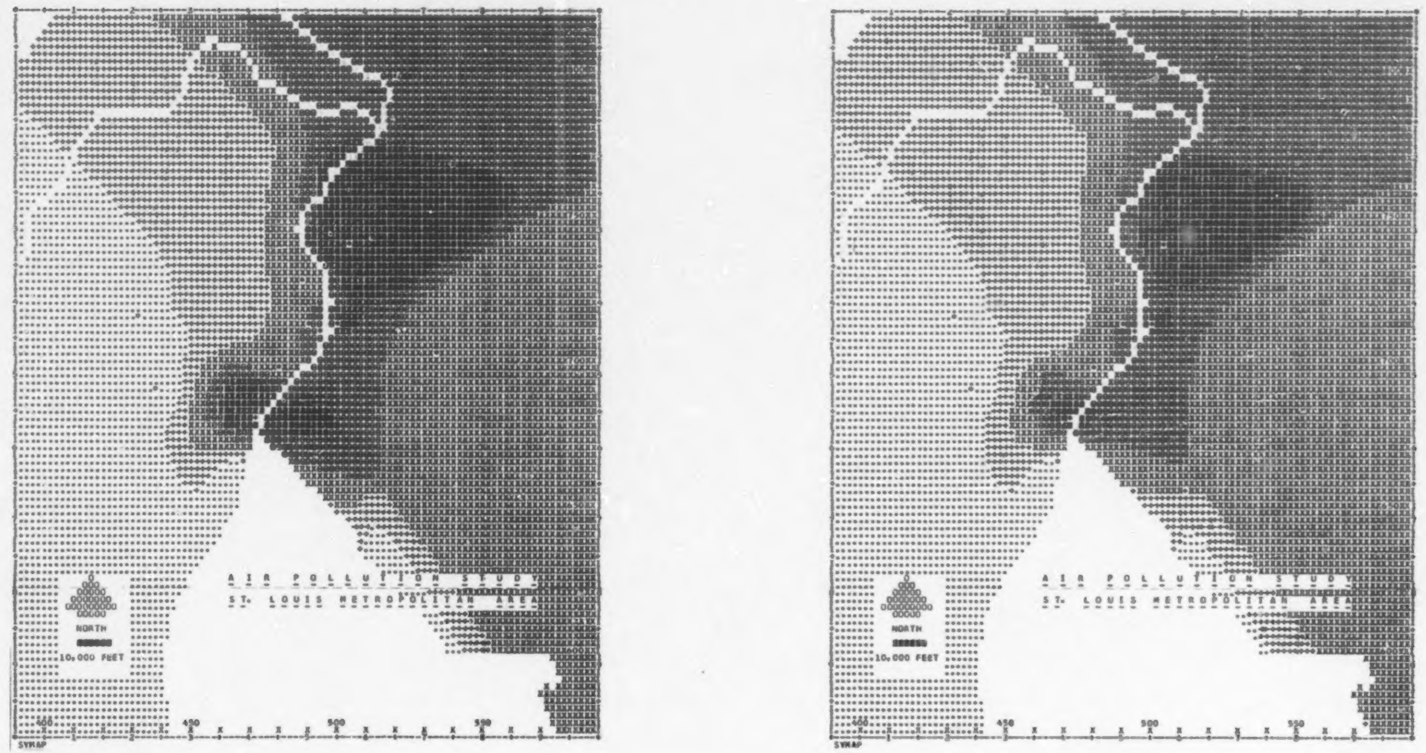

FIGURE A-10

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
Winter 1963-64 (Weekday Schedule)
a. Minimum b. Maximum



```
C      SUSPENDED PARTICULATES BY HIGH-VOLUME AIR    PLER
C      WINTER 1963-1964 (WEEKDAY SCHEDULE)
C      ARITHMETIC MEAN

DATA VALUE EXTREMES ARE          57.20       204.32

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       57.20      76.11     100.46     142.25     178.63
  MAXIMUM       76.11     100.46     142.25     178.63     204.32

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                 8.29      10.74      18.40      16.08      46.55

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3          4          5

  SYMBOLS

  FREQ.           3          3          4          3          3
```

```
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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

```
C      SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C      WINTER 1963-1964 (WEEKDAY SCHEDULE)
C      GEOMETRIC MEAN

DATA VALUE EXTREMES ARE          52.16       208.57

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM       52.16      65.83      91.04     131.54     168.49
  MAXIMUM       65.83      91.04     131.54     168.49     208.57

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                 8.74      16.11      25.90      23.63      25.62

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3          4          5

  SYMBOLS

  FREQ.           3          3          4          5          3
```

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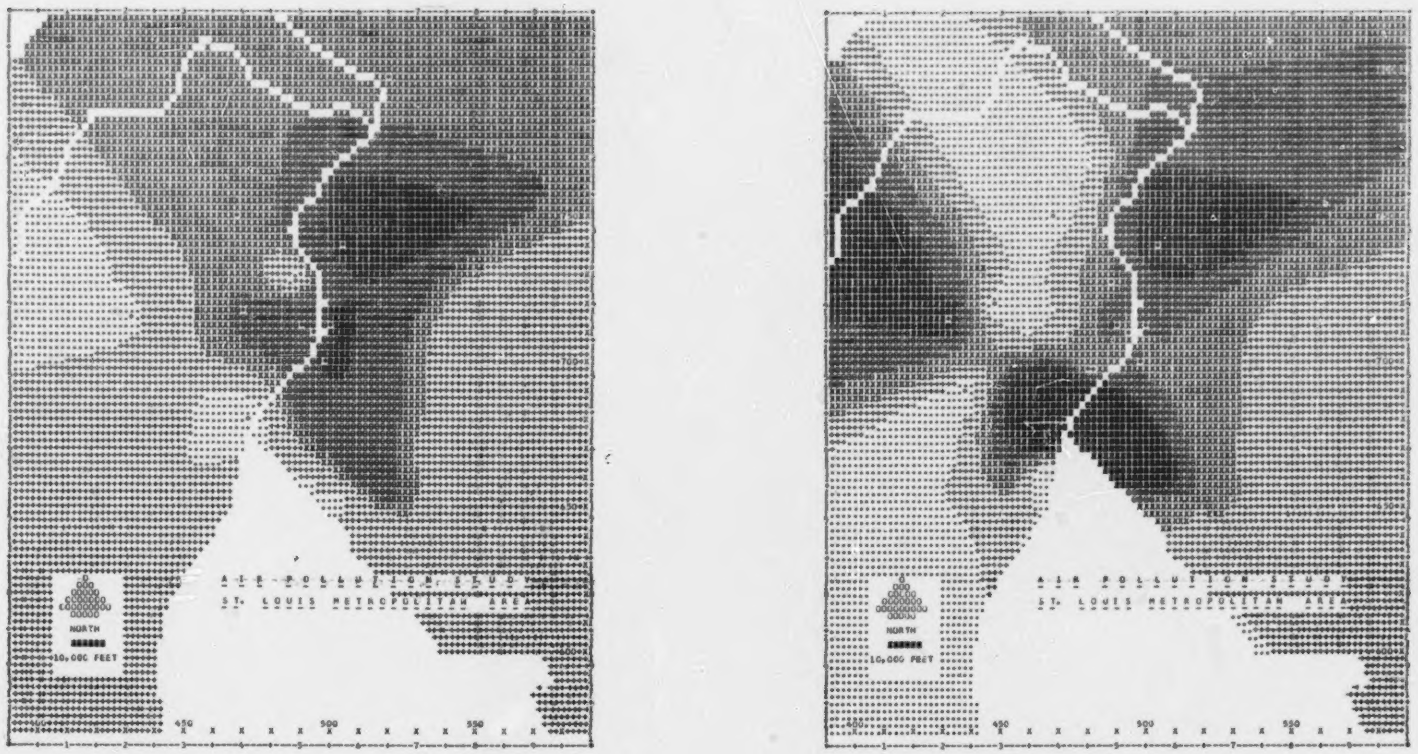
SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35-36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

FIGURE A-11

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
Winter 1963-64 (Weekday Schedule)

a. Arithmetic Mean b. Geometric Mean



```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     JULY 1963-JUNE 1964 (RANDOM SCHEDULE)
C     MINIMUM

DATA VALUE EXTREMES ARE        11.00       76.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM      11.00      14.50      23.50      31.50      63.40
  MAXIMUM      14.90      23.50      31.50      63.40      76.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               6.00      13.23      12.31      49.00      19.38

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
  SYMBOLS
  FREQ.          3          4          3          4          3
```

```
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HARVARD UNIVERSITY            CAMBRIDGE, MASSACHUSETTS

SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35,36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     JULY 1963-JUNE 1964 (RANDOM SCHEDULE)
C     MAXIMUM

DATA VALUE EXTREMES ARE       171.00     1337.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
  MINIMUM     171.00     203.10     255.80     333.40     440.40
  MAXIMUM     203.10     255.80     333.40     440.40    1337.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               2.75       4.86       6.11       9.18      76.90

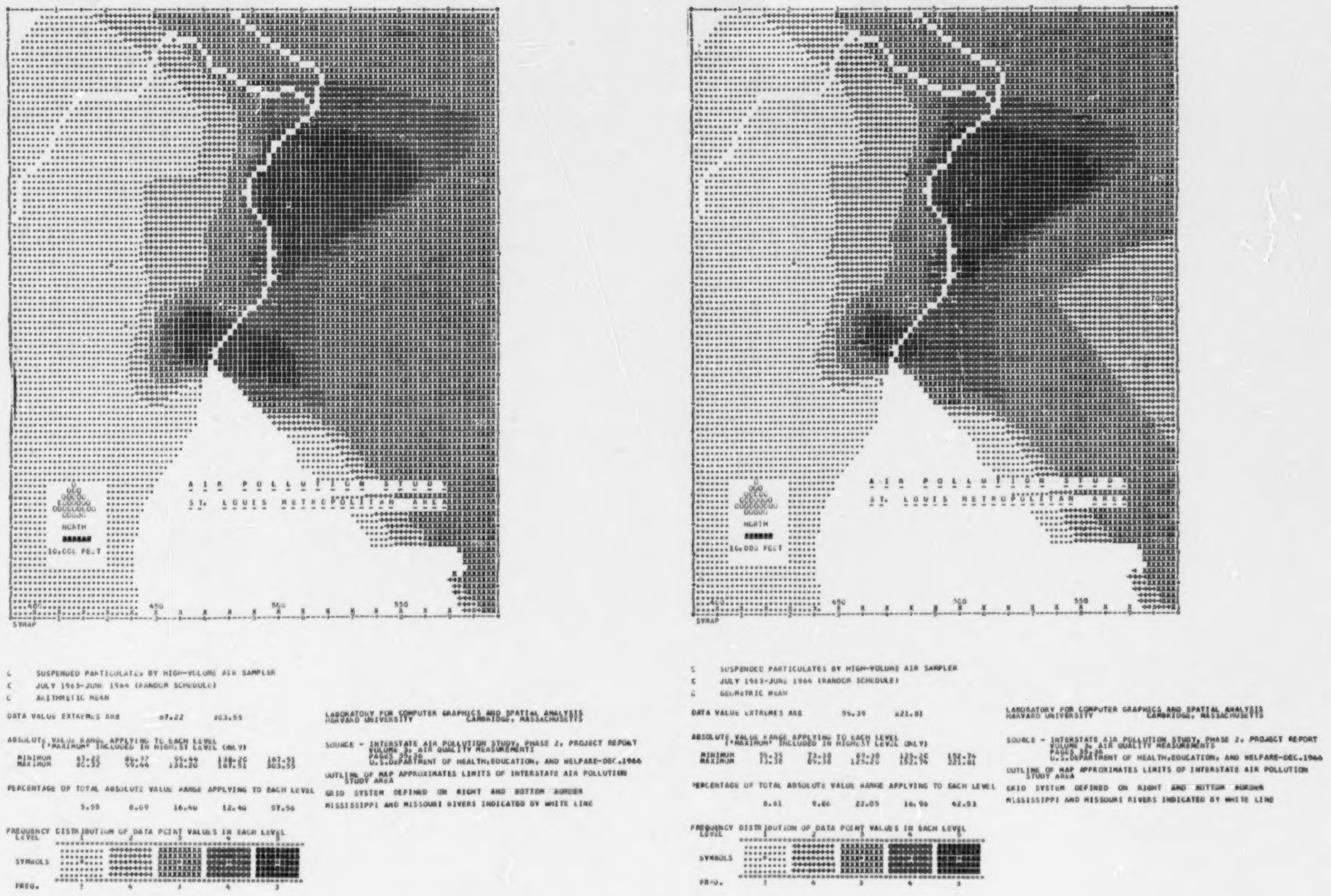
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
  SYMBOLS
  FREQ.          3          4          3          4          3
```

```
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY            CAMBRIDGE, MASSACHUSETTS

SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35,36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

FIGURE A-12

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
July 1963-June 1964 (Random Schedule)
a. Minimum b. Maximum



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C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     JULY 1963-JUNE 1964 (RANDOM SCHEDULE)
C     ARITHMETIC MEAN

DATA VALUE EXTREMES ARE         67.22      303.55

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        67.22      80.32      99.44     138.20     167.51
  MAXIMUM        80.32      99.44     138.20     167.51     303.55

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                  5.55       8.09      16.40      12.40      57.56

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3          4          5

  SYMBOLS

  FREQ.           3          4          3          4          3

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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35,36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

```
C     SUSPENDED PARTICULATES BY HIGH-VOLUME AIR SAMPLER
C     JULY 1963-JUNE 1964 (RANDOM SCHEDULE)
C     GEOMETRIC MEAN

DATA VALUE EXTREMES ARE         59.39      221.81

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        59.39      73.38      89.38     125.20     152.74
  MAXIMUM        73.38      89.38     125.20     152.74     221.81

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                  8.61       9.86      22.05      16.96      42.53

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3          4          5

  SYMBOLS

  FREQ.           3          4          3          4          3

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SOURCE - INTERSTATE AIR POLLUTION STUDY, PHASE 2, PROJECT REPORT
         VOLUME 3, AIR QUALITY MEASUREMENTS
         PAGES 35,36
         U.S.DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
OUTLINE OF MAP APPROXIMATES LIMITS OF INTERSTATE AIR POLLUTION
    STUDY AREA
GRID  SYSTEM  DEFINED  ON  RIGHT  AND  BOTTOM  BORDER
MISSISSIPPI AND MISSOURI RIVERS INDICATED BY WHITE LINE
```

FIGURE A-13

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Suspended Particulates by High-Volume Air Sampler
July 1963-June 1964 (Random Schedule)
a. Arithmetic Mean b. Geometric Mean

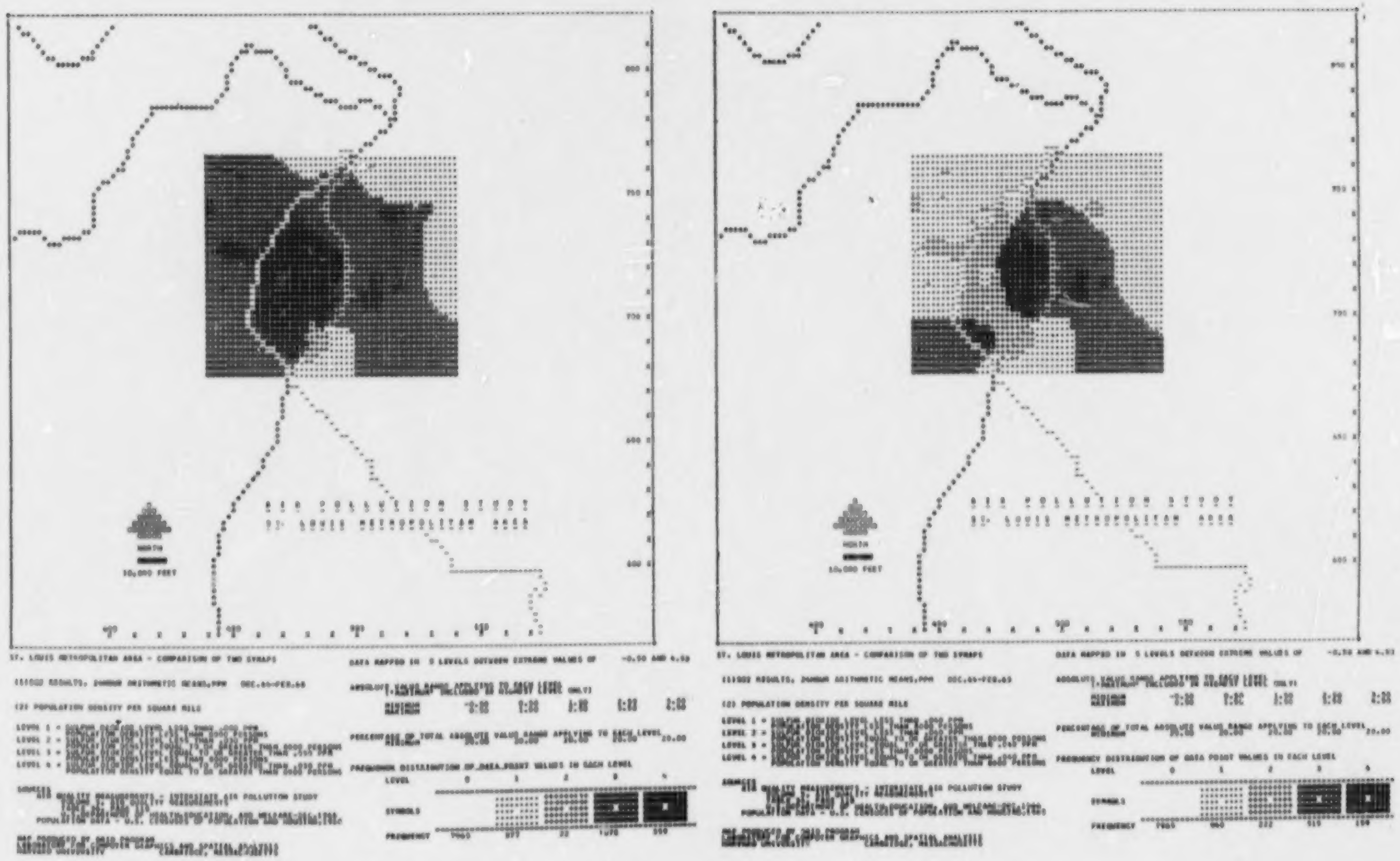
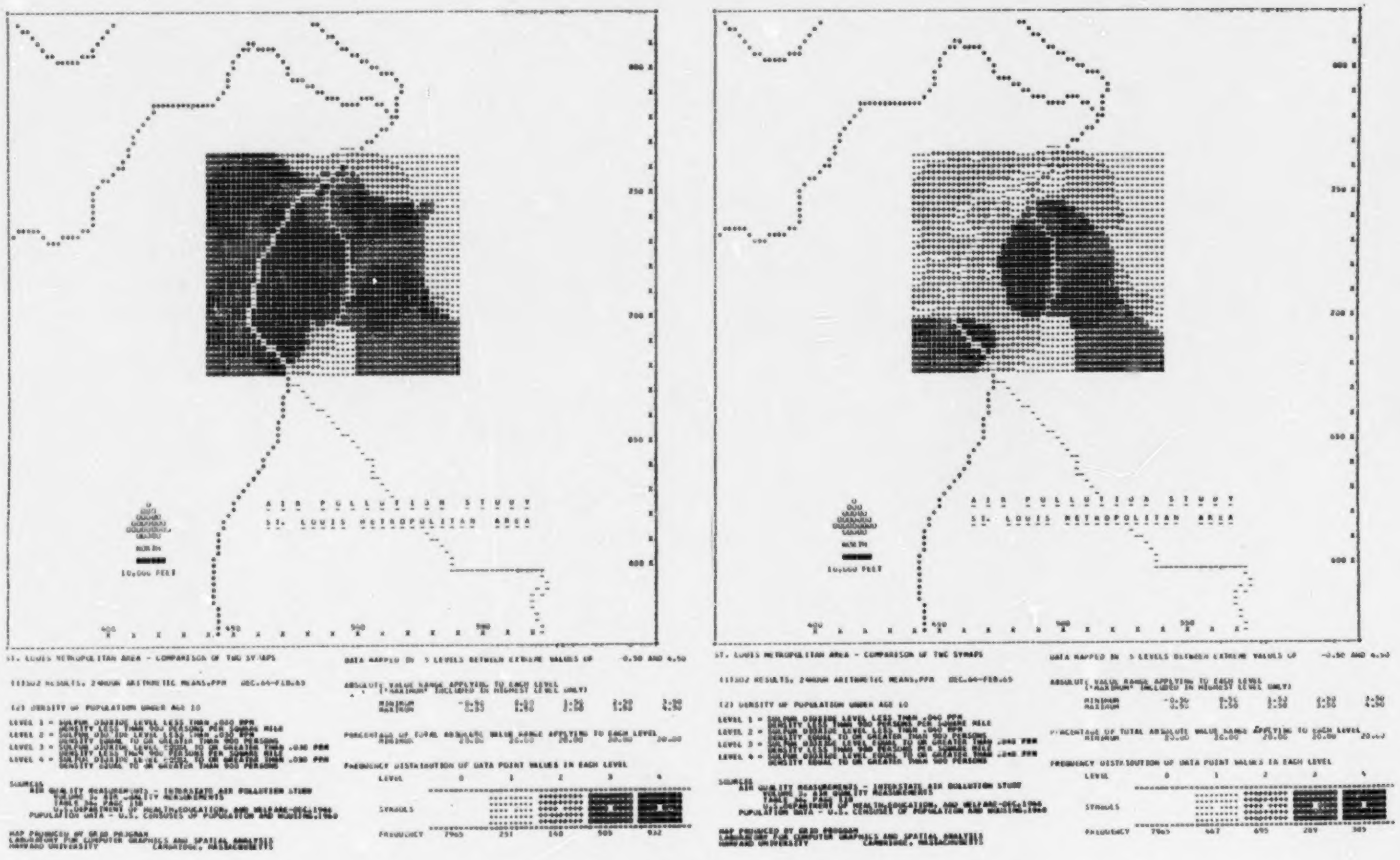

NORTH
10,000 FEET
AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
NORTH
10,000 FEET
AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA

FIGURE A-14

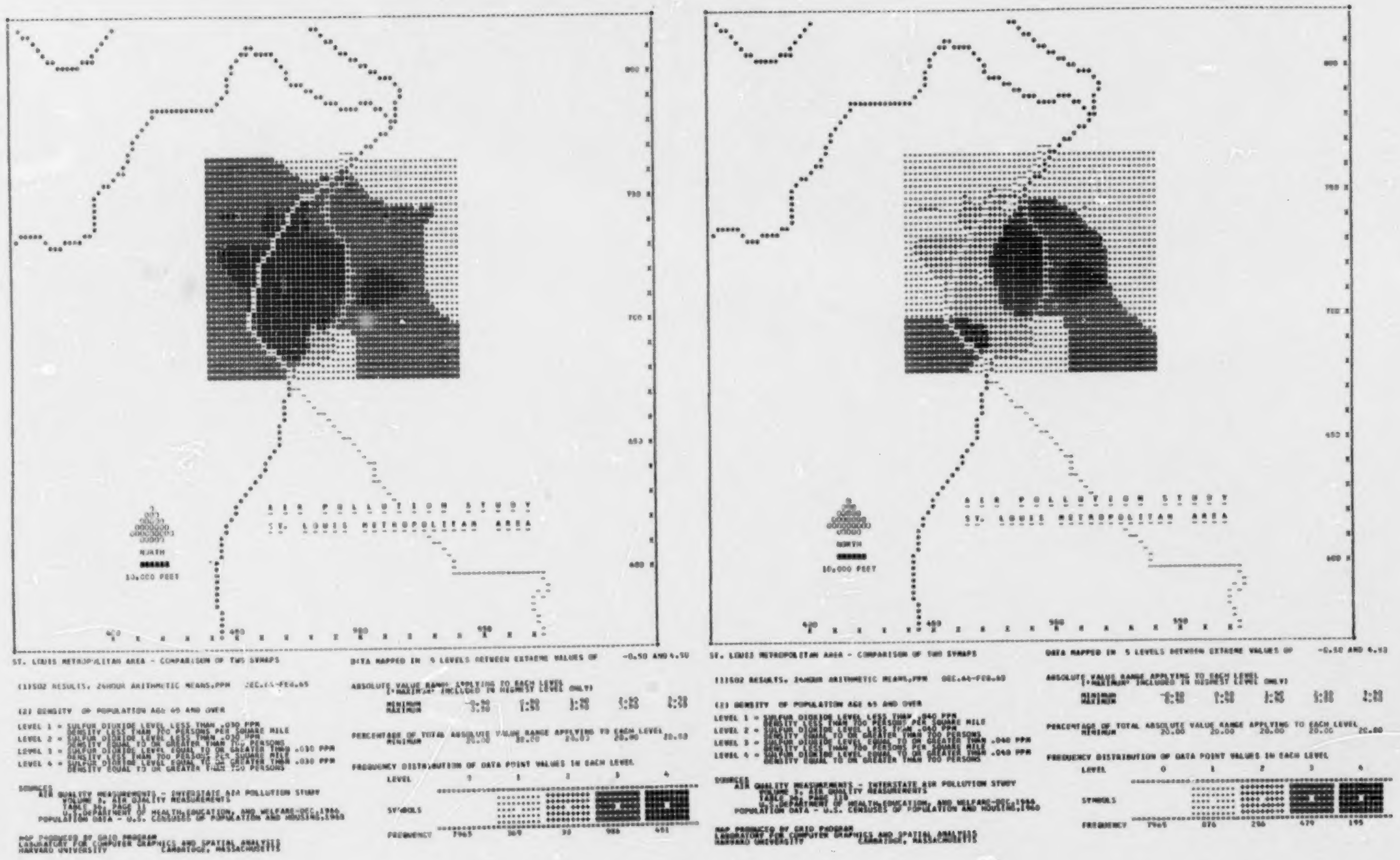
ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Comparison Map — Winter 1964-65
SO_2 Level versus Population Density
a. Using .03 Level b. Using .04 Level



AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
10,000 FEET
AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
10,000 FEET

FIGURE A-15

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Comparison Map
SO_2 Level versus Density of Population under Age Ten
a. Using .03 Level b. Using .04 Level



ST. LOUIS METROPOLITAN AREA - COMPARISON OF TWO SYMAPS

(1)SO2 RESULTS, 24HOUR ARITHMETIC MEANS,PPM DEC.64-FEB.65

(2) DENSITY OF POPULATION AGE 65 AND OVER

LEVEL 1 = SULFUR DIOXIDE LEVEL LESS THAN .030 PPM DENSITY LESS THAN 700 PERSONS PER SQUARE MILE
LEVEL 2 = SULFUR DIOXIDE LEVEL LESS THAN .030 PPM DENSITY EQUAL TO OR GREATER THAN 700 PERSONS
LEVEL 3 = SULFUR DIOXIDE LEVEL EQUAL TO OR GREATER THAN .030 PPM DENSITY LESS THAN 700 PERSONS PER SQUARE MILE
LEVEL 4 = SULFUR DIOXIDE LEVEL EQUAL TO OR GREATER THAN .030 PPM DENSITY EQUAL TO OR GREATER THAN 700 PERSONS

SOURCES
AIR QUALITY MEASUREMENTS - INTERSTATE AIR POLLUTION STUDY
VOLUME 3, AIR QUALITY MEASUREMENTS
U.S. DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
POPULATION DATA - U.S. CENSUSES OF POPULATION AND HOUSING,1960

MAP PRODUCED BY GRID PROGRAM
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS

DATA MAPPED IN 5 LEVELS BETWEEN EXTREME VALUES OF -0.50 AND 4.50

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	0	1	2	3	4
FREQUENCY	7965	369	30	986	491

ST. LOUIS METROPOLITAN AREA - COMPARISON OF TWO SYMAPS

(1)SO2 RESULTS, 24HOUR ARITHMETIC MEANS,PPM DEC.64-FEB.65

(2) DENSITY OF POPULATION AGE 65 AND OVER

LEVEL 1 = SULFUR DIOXIDE LEVEL LESS THAN .040 PPM DENSITY LESS THAN 700 PERSONS PER SQUARE MILE
LEVEL 2 = SULFUR DIOXIDE LEVEL LESS THAN .040 PPM DENSITY EQUAL TO OR GREATER THAN 700 PERSONS
LEVEL 3 = SULFUR DIOXIDE LEVEL EQUAL TO OR GREATER THAN .040 PPM DENSITY LESS THAN 700 PERSONS PER SQUARE MILE
LEVEL 4 = SULFUR DIOXIDE LEVEL EQUAL TO OR GREATER THAN .040 PPM DENSITY EQUAL TO OR GREATER THAN 700 PERSONS

SOURCES
AIR QUALITY MEASUREMENTS - INTERSTATE AIR POLLUTION STUDY
VOLUME 3, AIR QUALITY MEASUREMENTS
U.S. DEPARTMENT OF HEALTH,EDUCATION, AND WELFARE-DEC.1966
POPULATION DATA - U.S. CENSUSES OF POPULATION AND HOUSING,1960

MAP PRODUCED BY GRID PROGRAM
LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS
HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS

DATA MAPPED IN 5 LEVELS BETWEEN EXTREME VALUES OF -0.50 AND 4.50

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
MINIMUM 20.00 20.00 20.00 20.00 20.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	0	1	2	3	4
FREQUENCY	7965	876	296	479	195

FIGURE A-16

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Comparison Map
SO_2 Level versus Density of Population over Age Sixty-five
a. Using .03 Level b. Using .04 Level

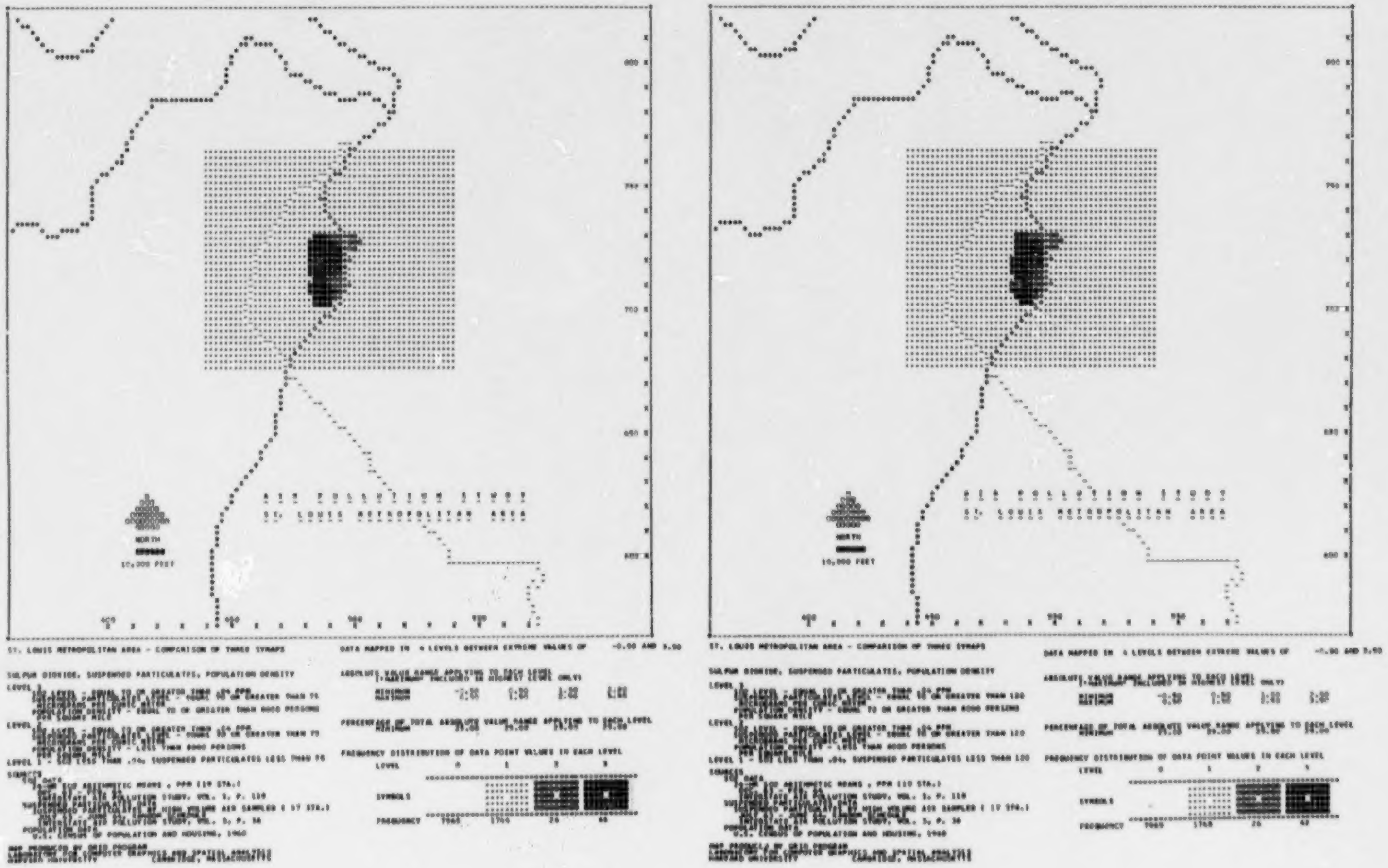

AIR POLLUTION STUDY
ST. LOUIS METROPOLITAN AREA
NORTH
15,000 FEET
ST. LOUIS METROPOLITAN AREA - COMPARISON OF THREE SYMAPS
SULPUR DIOXIDE, SUSPENDED PARTICULATES, POPULATION DENSITY
DATA MAPPED IN 4 LEVELS BETWEEN EXTREME VALUES OF -0.50 AND 3.50
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL
0
1
2
3
SYMBOLS
FREQUENCY

FIGURE A-17

ST. LOUIS REGION STUDY
St. Louis Interstate Air Pollution Study Area
Comparison Map
a. SO_2 (Winter 1963-64) Using .04 Level, Suspended Particulates (July 1963-June 1964) Using 75 μ/m^3 Level, and Population Density
b. SO_2 (Winter 1963-64) Using .04 Level, Suspended Particulates (July 1963-June 1964) Using 120 μ/m^3 Level, and Population Density